Competitive Relationships Between Sugar and Corn Sweeteners

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COMPETITIVE RELATIONSHIPS BETWEEN SUGAR AND CORN SWEETENERS

By Phillip E. Jones and F. G. Thomason

SUMMARY AND CONCLUSIONS

Competition among sweeteners is keenest between sugar and the two primary corn sweeteners: dextrose and corn sirup. There is also some competition between dextrose and corn sirup as well as between dry sugar and liquid sugar. In recent years, the dry form of corn sirup (corn sirup solids) has become increasingly important as a competitor with sugar and with dextrose and the conventional form of corn sirup. Consumption of the predominant sweetener, sugar, in 1950 was 7 times as large as that of the corn sweeteners combined; in 1935-39 it was 10 times as large. Other sweeteners such as honey, maple sugar and sirup, molasses, sugarcane sirup, refiners' sirup and sorgo sirup (now representing about 3 percent of total sweetener distribution) are used primarily to impart flavor and other special characteristics to the finished product.

United States supplies of sugar are obtained largely from domestically produced sugar beets and sugarcane, and from imports from Cuba and the Philippines. The annual quantity of sugar available for consumption during the prewar period of 1935-39 averaged 127.2 million 100-pound units; during 1950, the quantity equaled 148 million units, of which 10 million was liquid sugar.

Dextrose and corn sirup supplies are obtained almost entirely from corn produced and processed domestically. The average corn grind for domestic use averaged 65.9 million bushels during 1935-39, exceeded 133 million bushels during 1947 and in 1950 equaled 126 million bushels. During the prewar years 1935-39, dextrose and corn sirup sales averaged 2.4 and 10.3 million 100-pound units, respectively. The war year 1942, when the use of sugar was restricted, saw a rise of dextrose and corn sirup sales to 6.1 and 20.1 million units, respectively. Dextrose sales have maintained their trend and reached 7.3 million units in 1950, while corn sirup sales experienced a sharp decrease after the discontinuance of rationing and in 1950 totaled 14.8 million units.

Per capita consumption of the three primary sweeteners (sugar, dextrose, and corn sirup) has increased 4 percent since the prewar period. Per capita consumption of the predominant sweetener, sugar, is about the same as in the prewar period, whereas that of corn sirup has increased almost one-fourth and dextrose consumption has more than doubled.

The use of corn sweeteners has been accelerated by the trend toward industrial manufacture of processed food products formerly produced in

the home. The extent of this trend is indicated by the fact that industrial usage of sweeteners has more than doubled in the last 15 years, while population has increased only 19 percent. Food processing industries used less than a third of the sugar distributed in the United States prior to World War II but they now use slightly more than one-half. The housewife uses sugar almost exclusively in her cooking, baking, and canning while many industrial food processors use a combination of sugar and one or more of the corn sweeteners.

Except for the war years, sugar has represented about three-fourths of total sweeteners used by industry as a whole. The stability of this ratio, however, is not a significant measure of the competitive relationship between sugar and other sweeteners. There has been no change in the pattern of sweetener usage in the confectionery industry and beverage manufacturers have reduced slightly the use of corn sweeteners relative to sugar, but significant increases in the relative use of corn sweeteners have occurred in the baking, ice cream and canning industries. The confectionery and baking industries, which used corn sweeteners more extensively than the others in the prewar period, have not experienced as much business expansion as the others since that time. This situation accounts for the fact that the relative use of corn sweeteners by industry as a whole has not increased despite the significant increase in such usage by a majority of the industries.

The increase from 13 to 21 percent in the ratio of corn sweeteners to the total in the baking industry is due largely to replacement of sugar with dextrose in breadmaking. Many bakers reported that bread made with dextrose compares favorably with that made with sugar. It was also reported to be possible to substitute dextrose for sugar more completely in bread than in any other food product.

The increase in the use of corn sweeteners in the ice cream industry from 3 to 10 percent of total sweetener usage appears to be the result of a growing acceptance by many in the industry that quality ice cream can be produced at lower cost with a combination of sugar and corn sweetener, with up to 25 percent of the latter being used. The increase also has been associated with the growth in relative importance of sherbets and ices within the industry. The usage of dextrose and high-conversion corn sirup is relatively greater in these products than in ice cream, because most manufacturers believe a superior product is obtained by using a combination of sugar and one of the corn sweeteners.

The increase of corn sweetener usage from 5 to 12 percent of total sweetener usage in the canning and preserving industry has, in large part, been an outgrowth of research which indicated that use of a combination of sugar and corn sweeteners was desirable to exercise control over degree of sweetness and over-crystallization, and to bring out natural fruit flavors.

The decline since the prewar period in use of corn sweeteners in the beverage industry from 9 to 7 percent of total sweeteners is accounted

for by the relatively larger expansion in the production of soft drinks than of alcoholic beverages. Sugar represents a much larger proportion of total sweetener in soft drinks than in alcoholic beverages.

The major factors considered by a food processor in determining sweetener usage are differences in physical and chemical properties of various sweeteners, their relative prices, and restrictions imposed by Federal and State regulations and, to a lesser extent, advertising and sales programs, in-plant handling problems, consumer preference, and psychological factors.

The most important physical and chemical properties considered by a processor are: (1) relative sweetness; (2) flavor; (3) hygroscopicity; (4) solubility and crystallization characteristics; (5) density of liquid sweeteners and moisture content of solid sweeteners; (6) molecular weight, osmotic pressure and freezing point depression, and (7) fermentation and preservative properties. Sweeteners vary considerably with respect to these properties. Requirements also vary widely, according to the qualities desired in particular products.

Price differentials among the various sweeteners influence a food processor's choice, though often a price advantage is out-weighed by qualitative considerations, such as the physical properties mentioned above. There is a general, though not constant, price relationship between sugar and other sweeteners. Liquid sugar on a solids basis is priced at a small differential under granulated, but freight rates on liquid sugar tend to offset the price advantage for processors not located close to refineries. Dextrose prices are geared to sugar prices, with a favorable differential usually of about 18 or 19 percent. Corn sirup prices are geared primarily to the net cost of corn to the wet miller, though sugar prices set an upper limit on them. Because of differences in solids content and relative sweetness of corn sweeteners compared with sugar, the price difference per unit tends to overstate the savings which might result from replacing sugar with corn sweeteners.

Sweetener use in the manufacture of processed foods has been increasingly influenced for many years by both Federal and State regulations. At first these regulations leaned heavily in favor of sugar as an exclusive sweetener. Progressive revisions of these standards have generally been toward allowance of a much broader range of sweeteners. Apparent limitations on the use of corn sweeteners are generally well within the accepted practices of the food processing industries, although regulations governing the use of corn sirup tend to be more restrictive than those prescribed for dextrose.

The two types of Federal standards affecting the type or amount of sweetener used in food products are those of the Food and Drug Administration of the Federal Security Agency and those of the U. S. Department of Agriculture. Federal standards are now effective for canned fruits, canned vegetables, preserves, jams and jellies, fruit butters,

cocoa and chocolate, and sweetened condensed milk. In addition, standards have been proposed for frozen fruits, frozen desserts (ice cream), and bread. State regulations generally affect sweetener use in ice cream and soft drinks, which are as yet not covered by Federal standards.

During the past 4 years there has been a steady increase in the amount of sugar sold in liquid form, although liquid sugar in 1950 still represented only 6.7 percent of the total sugar distributed. The shift to liquid sugar usage has been occurring chiefly in locations near refineries, involving low freight charges, notably among large-scale manufacturers whose volume is such that savings on the lower cost ingredient and lower in-plant handling costs more than offset the cost of installing the equipment for handling it. Partly because of the convenience of mixing two liquid sweeteners together, processors who have shifted from dry to liquid sugar also tend to shift from dextrose to corn sirup insofar as qualitative considerations permit.

FUTURE TREND IN USAGE OF CORN SWEETENERS

With the notable exception of the use of dextrose in bread baking, corn sweeteners are rarely used alone, but are used in combination with sugar. Use of corn sweeteners as the sole sweetener is not practical in most food products because of certain characteristics which would be imparted to the products as a result of physical or chemical properties of the corn sweeteners. From 20 to 33 percent of total sweeteners usually is the maximum proportion represented by corn sweeteners. When used in these amounts, many food processors believe that their use in combination with sugar results in a finished product equally as good as when all sugar is used, and, at the same time, permits a lowering of ingredient costs.

Future trends in the over-all competitive relationship between sugar and corn sweeteners will be affected by the extent to which the use of sweeteners continues to be diverted from the household to industry and by the relative growth of the various food processing industries, but will be determined in more significant degree by the net impact upon individual industries of the factors influencing food processors' choice of sweetener. During the past two decades, the importance of these factors appears to have become fairly well established. It is to be expected that the upward trend in the use of corn sweeteners will continue.

INTRODUCTION

Need for the Study

For several years prior to World War II there was a steady increase in the production and use of corn sweeteners in the United States. Wartime curtailments in supplies of cane and beet sugar available for our domestic civilian requirements gave added impetus to this trend. It was reported that some manufacturers of sugar-containing products who used corn sweeteners for the first time during the war had found them acceptable and planned to continue their use after sugar again became readily available in the latter part of 1947. On the other hand, there were some who believed that the usage of corn sweeteners would be drastically curtailed after the end of sugar rationing. In addition to the variation in opinions as to the probable quantitative direction of the postwar shifts in corn sweetener usage, there was considerable difference of opinion relative to the basic factors influencing the shifts.

A thorough study of the competitive relationships between sugar and corn sweeteners was considered advisable because of lack of specific information as to the probable trend in the postwar use of corn sweeteners, the extent to which sugar was being replaced by corn sweeteners, the relative importance of the various corn sweeteners in all types of food products, and the primary factors which affect the choice of sweeteners for a given use. Accordingly, funds were made available under authority of the Research and Marketing Act of 1946 to carry out such a study, the results of which are summarized in this report. It is believed that this report will provide useful information to those in the sugar and corn sweetener industries, to manufacturers of products containing either or both types of sweeteners, and to Federal and State agencies responsible for the formulation of policies affecting their utilization.

Scope and Objectives

This study is confined to an analysis of the competition between sweeteners used industrially in making bakery products, ice cream, confectionery, soft drinks, and canned, frozen, or preserved foods. It is estimated that in 1949 approximately 94 percent of the sugar which was used for the commercial production of sweetened foods was used in these products. Except for corn sirup used in blended sirups, even larger proportions of the corn sweeteners were used in these products. No attention has been given in this study to the use of sweeteners for making any of these products in the home, nor to direct household or restaurant consumption of sugar and corn sirup. While the primary sweeteners under study here are the various types of sugar and corn sweeteners, some mention will be made of other sweeteners, such as molasses and honey. An analysis is made of how each of the three types of corn sweeteners--dextrose, corn sirup, and corn sirup solids--competes with sugar, and attention is given to the effect upon this competitive pattern of utilizing sugar in liquid rather than in crystalline form.

The primary objectives of this study are twofold: (1) To determine statistically the extent of competition between sugar and the corn sweeteners in the production of processed foods; and (2) to ascertain the principal factors governing an industrial user's choice of sweetening agent or agents in making a given product.

Data Used in This Study

In carrying out this study, much pertinent primary and secondary information has been brought together for analysis. Primary data assembled include information from primary distributors of sugar and dextrose relative to deliveries of these products according to use-classification and data obtained from surveys of industrial users of sugar and corn sweeteners. Secondary data used include production, distribution, and price data assembled from the records of the U. S. Department of Agriculture; technological research data from both colleges and other research institutions, and from food processors; and information concerning the effect of Federal and State regulations on the use of sweeteners.

New Reports on Sugar and Dextrose Usage Instituted

Because data were not available on the quantities of sugar and dextrose currently being used by the various types of industries using these sweeteners, a system of voluntary reporting of such information by the primary distributors of these products was instituted. Primary distributors of dextrose consist of the wet corn milling companies producing this commodity, while primary distributors of sugar are the cane sugar refiners, beet sugar processors, and importers of offshore refined and other direct-consumption sugars. No attempt was made to obtain similar information from the domestic producers of direct-consumption sugars unless such producers were also refiners. There are from 15 to 20 producers of these types of sugars in Louisiana and Florida, but they distribute only about 1 percent of the total United States annual sugar supplies. Primary distributors supplying information quarterly since January 1, 1949, relative to their deliveries (sales) by types of customer represent 100 percent of the total dextrose distribution and approximately 97 percent of total sugar distribution. Copies of the official reporting forms--SU-64 for sugar and Grain-288 for dextrose--are included in the appendix.

In addition to the submission of current information on deliveries (sales) by types of customers, the manufacturers of corn sweeteners, cane sugar refiners, beet sugar processors, and sugar importers and brokers have supplied additional and heretofore unpublished data relative to sales by use categories for prior years (1935-48), as well as information on prices and pricing policies.

Surveys of Major Sweetener-Using Food Processing Industries

In order to obtain firsthand information about industrial users' experiences with sugar and corn sweeteners, personal interviews were held during the last half of 1948 and the first half of 1949 with representative manufacturers of sweetener-containing products. These manufacturers were interrogated as to the type and amount of sweetener then being used and as to their wartime experiences with modifications in type or percentages of

sweeteners used. They also were asked to indicate the primary factors affecting their choice of sweetening agent or agents; including the importance of such factors as price differentials, physical and chemical properties of the various sweeteners, and Federal and State food regulations. The individuals contacted were general managers, vice presidents in charge of production, plant superintendents, or chemists, depending largely on the type of organization of the company. A total of 718 contacts were made. However, a much larger number of companies are represented by these surveys because of centralized control over sweetening policies in the case of many soft-drink manufacturers, bakery organizations, and ice-cream producers. The 718 interviews made were distributed among manufacturers of the various sweetened products under study herein as follows:

Bakery products	108
Canned foods	83
Confectionery	138
Ice creams, sherbets, and ices	125
Frozen fruits	38
Preserves	120
Soft drinks	106

While a large proportion of the surveys were made in cities in which there is a concentration of sweetener-using industries, some were made in other areas to insure adequate geographic coverage. States, cities, or areas in which surveys were made include the following:

New England States:

Maine--Portland.
Massachusetts--Amherst, Boston, Cambridge, Everett, Hanson, Littleton, Lynn, Malden, Medford, Nabnasset, Natick, North Andover, Somerville, South Deerfield, Worcester.

Middle Atlantic States:

New York--East Williamson, Geneva, Ithaca, Manchester, Newark, New York, Rochester, Sodus, Wolcott.
New Jersey--Newark.
Pennsylvania--Bethlehem, Biglerville, Hanover, Harrisburg, Hershey, Lancaster, Philadelphia, Pittsburgh.

Southern States:

Delaware--Bridgeville.
District of Columbia.
Florida--Forest City (Orlando), Highland City, Kissimmee, Lake Alfred, Lakeland, Lake Wales, Miami, Orlando, Tampa, Winter Haven.
Georgia--Atlanta, Concord, Griffin, Macon, Zebulon.
Kentucky--Covington, Louisville.
Louisiana--New Orleans.

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Maryland--Baltimore, Cambridge, Easton, Greensboro.
Tennessee--Bells, Chattanooga, Dayton, Knoxville, Nashville, Portland.
Texas--Dalas, Ft. Worth, Houston.
Virginia--Alexandria, Charlottesville, Crozet, Fredericksburg, Front Royal, Richmond, Winchester.

North Central States:

Illinois--Chicago, Evanston.
Iowa--Bettendorf, Davenport.
Michigan--Benton Harbor, St. Joseph, Traverse City.
Minnesota--Le Sueur, Minneapolis, St. Paul.
Missouri--Kansas City, St. Louis.
Ohio--Cincinnati.
Wisconsin--Columbus, Madison, Milwaukee, Sturgeon Bay, Sussex.

Western States:

California--Alameda, Berkeley, Greater Los Angeles, Oakland, Palo Alto, Redwood City, San Francisco, San Jose, Sunnyvale.
Colorado--Denver.
Oregon--Corvallis, Gresham, Hillsboro, Portland.
Washington--Mount Vernon, Seattle, Tacoma.

In selecting the firms to be contacted, assistance was solicited from trade associations representing the producers of sweetener-containing products. The associations which advised the Department in developing a representative sample and, in some cases, arranging for interviews, include the following:

American Bakers Association
American Bottlers of Carbonated Beverages
Assiciated Retail Bakers of America
Association of Cocoa and Chocolate Manufacturers of the United States
Canners League of California
Florida Canners Association
Independent Biscuit Manufacturers Association
International Association of Ice Cream Manufacturers
National Association of Food Chains
National Association of Frozen Food Packers
National Canners Association
National Preservers Association
Wisconsin Canners Association

For each product under consideration in this study, an estimate has been made of the percentage of total United States production which is represented by the companies surveyed. Such estimates are based in part on the estimates of the above-listed trade associations, and in part on the proportion of each group's sugar use represented by the companies surveyed in each group. Total sugar use for each group and usage of individual companies was that reported for purposes of establishing rationing bases under the wartime rationing program.

In arriving at estimates of coverage of an industry by the companies surveyed, the total production of companies having more than one plant is included if the company official interviewed determined the sweetener policy for the entire company. For example, an entire national organization of a bread baking firm or ice-cream manufacturer may have been covered by one interview. Similarly, if a soft-drink concentrate manufacturer either makes a finished sirup or stipulates the sweetener policy of the franchised bottlers who add all or a part of the sweetener, the total volume of production of that drink is included in arriving at the proportion of the industry covered. However, if the chain members or franchise holders make their own individual decisions with regard to types and amounts of sweeteners, only the production of the firms or plants surveyed were included in arriving at percentages of coverage. For the major sweetener-containing products under consideration in this study, the estimated coverage, as a percentage of total United States production of the commodity, arrived at in this manner, is as follows:

Bakery products (total).....	40 to 45
Bread only	55 to 60
Canned foods	30 to 35
Confectionery	45 to 50
Ice cream, sherbets, and ices	35 to 40
Frozen fruits	55 to 60
Preserves	55 to 60
Soft drinks	70 to 75

The firms whose officials were interviewed were selected to give adequate coverage of each segment of those industries which include different types of a product. For example, in selecting the confectionery manufacturers, care was taken to include companies which would give representation to all types of confectionery products, including creams, fondants, hard candy, caramels, nougats, marshmallows, etc. Similarly, soft-drink manufacturers were chosen which would give adequate coverage for all the major types of soft drinks--cola, gingerale, root beer, lemon, lime, etc. This, of course, is very important in many industries because the types and amounts of acceptable sweeteners vary considerably according to the particular type, or variety, of a product being produced.

Interviews with Research Groups

In order to obtain firsthand information from those currently engaged in research on usage of the various sweeteners in processed foods, several food technicians and other research workers prominent in the food processing field were interviewed. Information obtained through discussions with these technicians has been coordinated with that received from the commercial food processors in reporting the current status of competition between sugar and corn sweeteners in the production of various products. Research organizations contacted include:

New England States:

University of Massachusetts
Food Technology Division
Amherst, Massachusetts

Arthur D. Little Company
Food Chemistry Division
Cambridge, Massachusetts

Tressler Research Laboratory
Westport, Connecticut

Middle Atlantic States:

New York Agricultural Experiment Station
Food Technological Research Division
Geneva, New York

Cornell University
Dairy Industry Department
Ithaca, New York

Lehigh University
Confectionery Research Division
Bethlehem, Pennsylvania

Drexel Institute
Home Economics Department
Philadelphia, Pennsylvania

Sugar Research Foundation
52 Wall Street
New York 5, New York

Corn Industries Research Foundation
1329 E Street, N. W.
Washington 4, D. C.

Pennsylvania Manufacturing Confectioners Association
Research Division
Philadelphia, Pennsylvania

National Dairies, Inc.
Research Laboratories
Oakdale, Long Island &
N.Y.C., New York

Freud Food & Chemical Laboratories
New Products Division
New York, New York

Southern States:

U. S. Department of Agriculture
Citrus Products Experiment Station
Winter Haven, Florida

Tennessee Valley Authority
Singleton, Tennessee

Southern States (Cont'd)

United States Department of Agriculture
Production and Marketing Administration
Processed Fruit Inspection Service
Winter Haven, Florida

United States Department of Agriculture
Bureau of Agricultural & Industrial Chemistry
Southern Regional Research Laboratory
New Orleans, Louisiana

Georgia Agricultural Experiment Station
Food Technology Department
Griffin, Georgia

Tennessee Agricultural Experiment Station
Food Technology Division
Knoxville, Tennessee

Florida Citrus Commission
Research Division
Lakeland, Florida

National Dairy Council
Tennessee Division
Nashville, Tennessee

North Central States:

University of Wisconsin
Dairy Research Department
Madison, Wisconsin

Dunwoody Industrial Institute
School of Baking
818 Wayzata Blvd.
Minneapolis 3, Minnesota

General Mills
Food Technological Research Division
Minneapolis, Minnesota

American Institute of Baking
Chicago, Illinois

Technical Baking Institute
Chicago, Illinois

W. E. Long Company
Chicago, Illinois

Western States:

Oregon State College
Food Industries Division
Corvallis, Oregon

University of California
Food Technology Division
Berkeley, California

National Canners Association
Western Laboratory
San Francisco, California

Analysis of Influence of Federal and State Regulations on Sweetener Usage

Analysis has been made of the effect of Federal and selected State regulations upon the type and/or amount of sweetener used. Federal regulations analyzed include those of the Food and Drug Administration and the United States Department of Agriculture. States for which regulations concerning sweetener use were studied are California, Colorado, Georgia, Illinois, Iowa, Louisiana, Massachusetts, Michigan, Mississippi, New Hampshire, New Mexico, New York, Ohio, Oregon, Pennsylvania, and Wisconsin.

Definition of Sweeteners as Used in this Study

Sugar: A disaccharide, of the chemical formula $C_{12}H_{22}O_{11}$, derived from either sugarcane or sugar beets. As used herein, sugar means cane and beet sugar in forms commonly suited to human consumption without further processing, namely, refined crystalline, liquid, invert, and other direct-consumption sugar. Maple sugar and corn sugar are not included in the term sugar as used herein.

Refined crystalline sugar: Sugar of principally crystalline character, produced in a cane sugar refinery or a beet sugar factory. Included are all grades of refined crystalline cane and beet sugar, whether white or brown, granulated or powdered, except the other direct-consumption sugars described below.

Other direct-consumption sugar: Cane sugar produced by factories which mill the sugarcane. These sugars are made directly from the sugarcane, instead of from raw sugar at a refinery, and are suitable for some uses without further refining. For the purposes of this study, direct-consumption sugar includes such types as "turbinados", "plantation granulated", and "washed raws", and not offshore refined sugar as defined in the Sugar Act.

Liquid sugar: Sirups made from cane and beet sugar. Liquid sugar is of three principal types: (1) sucrose sirup, i.e., just a solution of sugar in water, with practically no inversion of the sucrose. This type is sometimes referred to as a "simple sucrose" sirup or merely as a "simple" sirup; (2) partially inverted sugar sirups, i.e., products in which a portion of the sucrose has been "inverted", or converted into dextrose and levulose, either by adding acid and heating or by the use of the enzyme invertase; and (3) highly inverted sugar sirups, i.e., products in which a high proportion, or almost all, the sucrose has been converted into dextrose and levulose. Although from 90 to 95 percent of the sucrose may be inverted in this type, the product is still marketed in liquid form and is to be distinguished from the product known as invert sugar. The term "liquid sugar", while familiar to the sugar trade, is not recognized by the Food and Drug Administration as

being the commonly used name for this product under the Food, Drug and Cosmetic Act. The Food and Drug Administration does not believe that the consuming public is familiar with this term.

Invert sugar: A sugar which is almost completely inverted, giving equal parts of dextrose and levulose and little, if any, sucrose. This product has a greater density than inverted liquid sugar and is congealed by the crystallization of the dextrose. The levulose does not crystallize but remains in fluid form, thereby giving to invert sugar a creamy consistency.

Dextrose: A monosaccharide ($C_6H_{12}O_6$) produced by practically complete hydrolysis or conversion of starch. Since dextrose historically has been produced largely from corn starch, it is commonly called "refined corn sugar." It often is called merely "corn sugar", although there are types of corn sugar other than dextrose, these being the so-called crude, or 70° and 80° sugars, which are incompletely refined and used largely for brewing and non-food products. To the chemist the name "glucose" is synonymous with "dextrose", but to the layman glucose usually means corn sirup or a glucose-type sirup produced from sorghum, wheat, or potato starch. Dextrose is of two principal types, hydrate and anhydrous. The bulk of the dextrose produced is of the hydrate type which contains approximately 8 percent moisture; the anhydrous type contains less than 0.5 percent moisture.

Corn sirup: A product obtained from corn starch by partial hydrolysis, clarification, decolorization, and evaporation to sirup density. In general, there are three commercial classifications of corn sirup, which vary according to dextrose equivalent, (D.E.), the total reducing sugar content calculated as dextrose on a dry basis. These three classifications are low, regular or medium, and high conversion, with the D.E. usually being from 28 to 33 for the low conversion type, from 40 to 43 for the regular conversion type, and from 52 to 65 for high conversion sirups. Many people consider the expression "glucose" synonymous with corn sirup. Another term used in the trade is C.S.U., meaning "corn sirup unmixed."

Corn sirup solids: Essentially a dehydrated corn sirup. Most of the water in the sirup is removed, thereby permitting it to be packed and sold in bags.

Molasses: The edible co-product of the manufacture of sugar when some, but usually not all, of the crystallizable sugar in the sugarcane juice is removed by the crystallization process. As used in this report, the term molasses means only the types commonly used for edible purposes.

Sirups: (a) Refiners' sirup--An edible, liquid co-product obtained when crystalline sugar is produced in the process of refining raw cane sugar. The total soluble solids content of refiners' sirup consists of more than 6 percent of soluble non-sugar solids.

(b) Sugarcane sirup, sorgo (sorghum) sirup, and maple sirup--Sirups produced directly from the plant juice or sap by clarifying and evaporating only to the point where the sugars do not crystallize out of solution.

(c) Malt sirups and malt extracts--The evaporated extracts of malted barley, usually supplemented by the use of some corn product. There are two distinctly different types: Diastatic and non-diastatic, the former containing the enzyme diastase, which converts starch to maltose (malt sugar).

(d) Wheat sirups and potato sirups--Glucose-type sirups made from the partial hydrolysis of wheat or potato starch.

SUPPLY, DISTRIBUTION, AND USAGE OF SWEETENERS IN THE UNITED STATES

Sources of Supply for Sugar and Corn Sweeteners

Sugar - United States sugar supplies are obtained largely from sugar beets grown in the Mid-west, Rocky Mountain States, and the West Coast, from sugarcane produced in Louisiana and Florida, and inshipments of sugar from Hawaii, Puerto Rico, Cuba, and the Philippines. Small amounts of sugar also are received from the Virgin Islands and from foreign countries other than Cuba and the Philippines. Since 1934, except during World War II, the entry of sugar into the continental United States from foreign areas and the marketing of sugar by domestic areas has been regulated by a system of quotas. 1/

Legislation now in effect--the Sugar Act of 1948--provides basic quotas in short tons of raw value for the domestic areas as follows: Domestic beet area, 1,800,000; mainland cane area (Louisiana and Florida), 500,000; Hawaii, 1,052,000; Puerto Rico, 910,000; and the Virgin Islands, 6,000. A basic quota of 952,000 short tons of sugar (982,000 short tons, raw value) also is assigned to the Republic of the Philippines which is in conformity with a provision to that effect in the Philippine Trade Act of 1946. The difference in the sum of these basic quotas and the amount of sugar determined by the Secretary of Agriculture to be needed to meet the sugar requirements of consumers in continental United States for a specific year is allotted to Cuba and to foreign countries other than Cuba and the Republic of the Philippines on the basis of 98.64 percent and 1.36 percent, respectively. In addition, when one area cannot fill its quota, the unfilled portion is prorated to other areas which can supply the sugar.

The Sugar Act limits to about 600,000 short tons, raw value, the portion of the quotas for Hawaii, Puerto Rico, the Philippines, and Cuba, which may be filled by sugar which is brought into the continental United States and marketed for direct consumption without further refining or other improvement in quality. This sugar may be fully or partially refined or in raw form. The Act also establishes liquid sugar quotas in terms of wine gallons of 72 percent total sugar content for Cuba and the Dominican Republic, of 7,970,558 and 830,894, respectively. Such liquid quotas for Cuba and the Dominican Republic are in addition to the other quotas for these areas.

Most of the raw sugar entering the continental United States from offshore domestic areas and from foreign countries is refined in or near the seaport cities of Boston, New York, Philadelphia, Baltimore, Savannah, New Orleans, Galveston, and San Francisco. Smaller-scale sugar refineries

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1/ Quotas suspended September 11-December 31, 1939 and April 13, 1942-December 31, 1947.

also are located at Los Angeles, St. Louis, Milwaukee, Chicago, and Indianapolis. The locations of U. S. sugar refineries operating on January 1, 1951 are shown in Figure 1 and are listed in the Appendix.

Raw sugar made from sugarcane produced in Louisiana is refined by the nine refineries located in the State. (These refineries also process offshore raws.) A few of the raw sugar mills in Louisiana produce direct-consumption types of raw sugar largely as a joint product with the production of edible sugarcane molasses. Most of the sugarcane grown in Florida is processed into raw sugar by mills located there. It is then shipped to and refined at Savannah, Ga. A very small amount of direct-consumption sugar made from Florida sugarcane also is marketed by the Florida mills. Sugar beets grown in the United States are processed in 73 sugar beet factories (1950-51) located in 16 states as shown in Figure 1.

Corn Sweeteners - Corn sweeteners are produced by the manufacturers of corn starch. The manufacturing group as a whole is termed the "wet corn milling industry" because large quantities of water are used in separating the various parts of the corn kernel. The manufacturers are also identified as "corn refiners" because the chemical process of deriving dextrose and corn sirup from corn is essentially a refining process. 2/ The wet corn milling plants are located principally in the Mid-west near sources of grain supplies. (See Figure 2)

The principal products of the wet corn milling industry are corn starch, corn sirup, and corn sugar; the most important by-products are oil, hydrol (corn-molasses), feeds, and dextrins. The corn sugars may be completely or partially refined; the completely-refined sugars are called dextrose, and the partially-refined ones are termed crude sugars, or "70 and 80 sugars." 3/

Corn sirup may be made at different densities and with quite a variation in degree of conversion. Most corn sirup is produced at densities of 42° to 45° Baumé, with the bulk of the production being at either 42° or 43°. In terms of degree of conversion, (from starch to sirup) corn sirups may be of low, regular, or high-conversion types. Low and regular conversion corn sirups are made with straight acid conversion, while high-conversion corn sirups may be made either by that process or by a combination acid-enzyme process. It is estimated that about three-fourths of the corn sirup production is of the regular conversion type, described herein as "regular corn sirup." Corn sirup may also be dried and marketed in a solid form; such a product is known commercially as "corn sirup solids."

2/ The plant at Corpus Christi, Tex. uses grain sorghums rather than corn.
3/ See page 13 for explanation of terms.

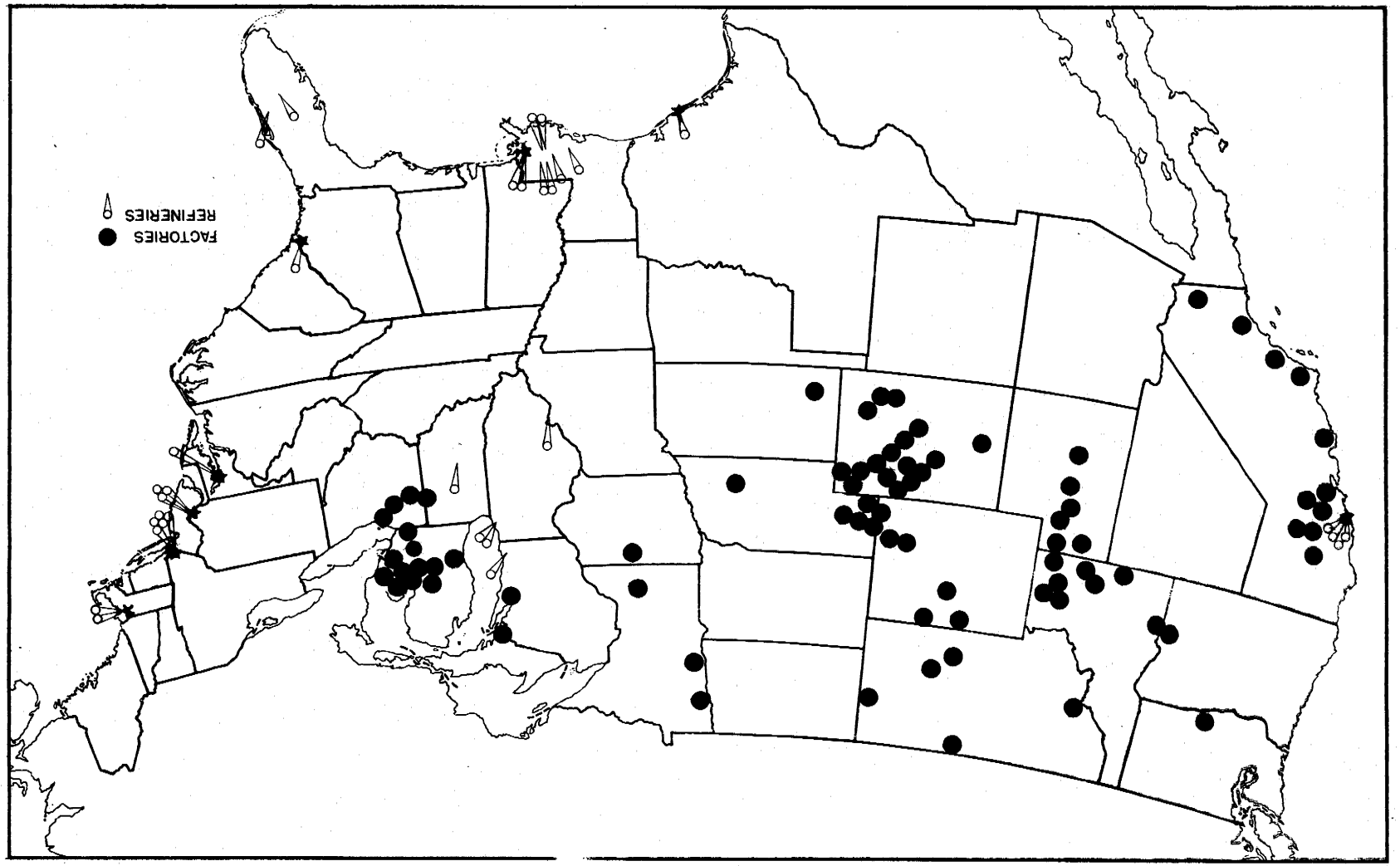

Figure 1.--Cane sugar refineries and beet sugar factories, United States, 1950-51.

Source: Appendix, Tables 32 and 33.

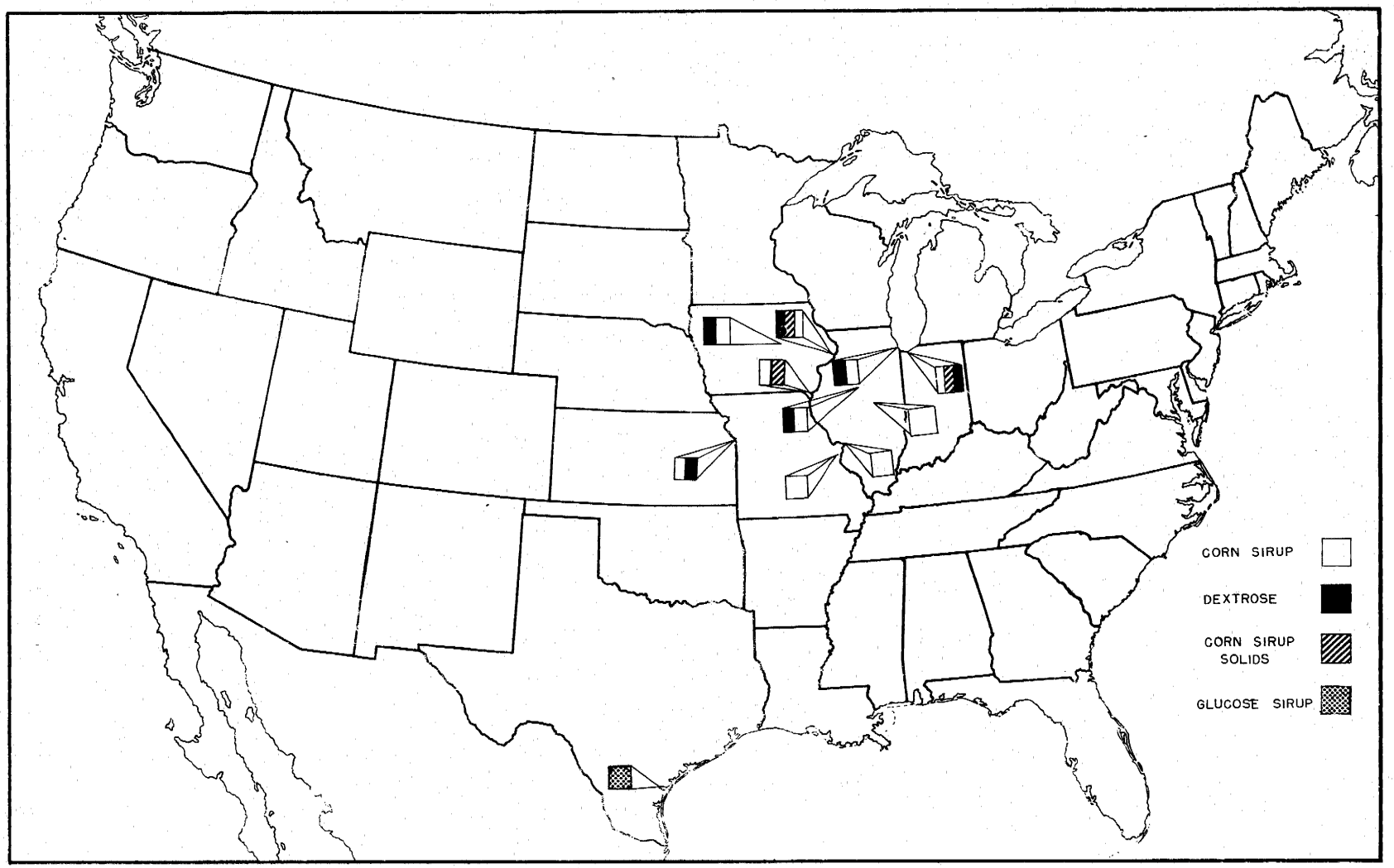

Figure 2.--Location of corn refineries and type of sweetener produced, United States, 1950-51.

Source: Appendix, Table 34.

Total Sweetener Distribution Domestically

Pre-war Period - Quantity-wise, sugar is by far the most important of all the sweeteners. From 1935 to 1939 annual cane and beet sugar available for United States consumption averaged about 126.5 million 100-pound units, as produced. Dextrose distribution during this period averaged only about 2.4 million bags each year, while annual sales of corn sirup were about one billion pounds. Smaller quantities of other sweeteners, such as maple sugar and sirup, honey, molasses, sugarcane sirups, and refiners' sirups also were available to United States consumers during these years. (See Table 1)

World War II Controls Period - The amount of sugar available for United States consumption during the period 1943 through 1946 was reduced considerably, largely as a result of the loss of supplies from the Philippines, because of shipping difficulties and because of the need for supplying other countries with a portion of the total sugar available. On the other hand, even though corn supplies available to wet corn millers for grinding were allocated during World War II, the wet-process grind during this period was considerably above the 1935-39 level. The wet millers ground from 60 to 80 million bushels of corn annually prior to World War II. (See Figure 3) The average grind for domestic use for 1935-39 equaled 65.9 million bushels. During the war years of 1942 and 1943 the grind for domestic use exceeded 122 million bushels or 186 percent of the pre-war average. Reductions in corn supplies during 1944, 1945, and 1946 resulted in a reduction in grind to about 115 million bushels.

Annual sales of dextrose and corn sirup followed the general pattern of the corn grind of the wet milling industry during the wartime years. Corn sirup sales reached a peak of over two billion pounds in 1942, almost double the 1935-39 average; while dextrose sales in 1942 were 2½ times the average for the five years ending in 1939. (Table 1)

Post-war Period - Total sugar supplies available for United States consumption after 1946 have exceeded those which prevailed before World War II and in 1950 equaled more than 148 million bags. With the resumption of plentiful sugar supplies after World War II, the volume of corn sirup sales dropped sharply. Monthly data on sales of corn sirups reveal that sales of this product started their slide in June of 1947 and continued almost without interruption for about a year; May 1948 sales were only a little more than 89 million pounds, less than half of those for the corresponding month in 1947. The principal reasons for the sharp decline in corn sirup sales during this period were the discontinuance of sugar rationing to industrial users in July 1947, and the collapse of demand for mixed table sirups during the latter part of that year. Although corn sirup sales recovered somewhat in late 1948 and early 1949, they were in both years much below 1946-47 levels. However, corn sirup sales during 1950 were at the rate of 143.5 percent of the pre-war period of 1935-39. In contrast to the drop in corn sirup sales with the end of the World War II sugar shortage, total sales of

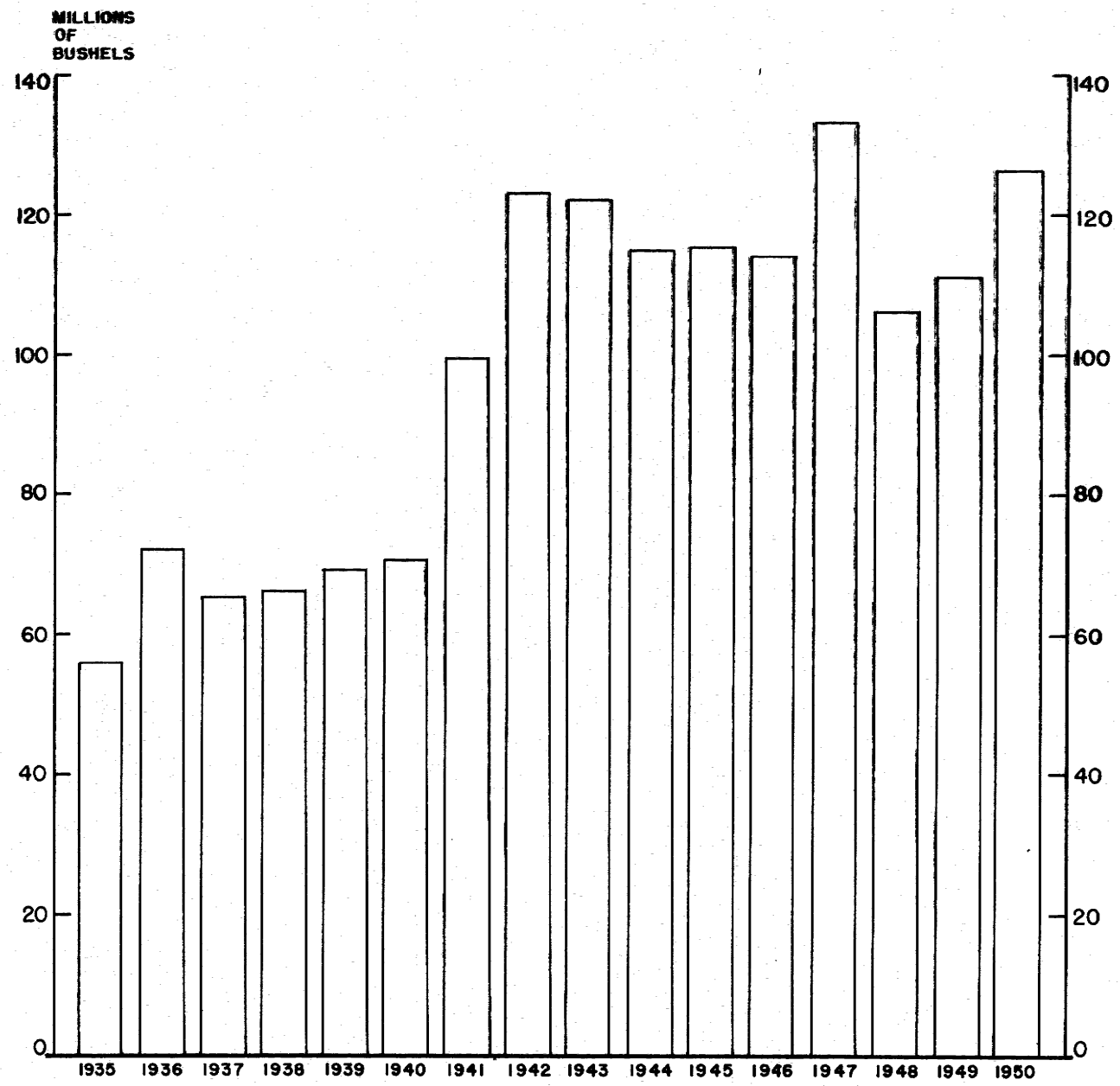

Figure 3.--Quantity of corn processed for domestic consumption by the wet-milling industry, United States, 1935-50.

Source: Appendix, Table 41.

Table 1 - QUANTITIES OF SWEETENERS AVAILABLE FOR DOMESTIC CONSUMPTION, UNITED STATES 1935-50
(100 Pound Units, as produced)

Year	Sugar 1/	Dextrose 2/	Corn Sirup 3/	Cane Sirup and Edible Molasses 4/	Refiners' Sirup	Maple Sirup	Maple Sugar	Honey	Sorgo Sirup
1935	125,725,367	1,683,494	9,124,820	3,591,360	294,170	402,160	31,610	1,600,350	2,146,914
1936	128,014,731	2,157,720	11,222,246	3,679,870	283,160	267,190	69,280	1,787,290	1,874,565
1937	126,413,755	2,443,600	10,087,343	3,357,500	276,010	275,550	68,290	1,628,430	1,494,108
1938	126,192,813	2,667,356	10,403,664	3,460,510	292,180	305,140	46,510	2,219,930	1,441,556
1939	126,204,924	3,205,911	10,874,186	3,084,560	123,060	303,160	99,880	1,805,160	1,317,508
1940	125,270,779	3,614,604	10,826,783	3,586,260	189,980	332,310	45,210	2,051,020	1,177,984
1941	140,987,997	5,154,954	12,159,443	2,483,330	282,220	242,990	50,150	2,265,730	1,167,340
1942	122,789,683	6,089,517	20,118,821	3,614,680	710,000	368,610	77,750	1,985,390	1,220,604
1943	118,653,002	5,940,626	17,900,574	3,165,870	1,386,120	292,930	51,340	2,280,620	1,585,584
1944	134,775,792	5,538,814	18,064,489	4,003,860	1,722,370	300,410	44,480	,135,510	1,370,754
1945	113,598,509	5,682,762	18,267,380	3,307,740	2,531,400	121,330	41,960	539,040	1,345,460
1946	105,221,787	5,567,669	17,606,684	5,129,980	1,677,720	168,300	45,790	2,335,510	1,137,675
1947	132,613,944	6,428,897	19,392,133	4,360,320	1,131,920	275,660	43,690	2,476,670	1,178,377
1948	142,468,373	6,121,464	12,945,199	3,046,280	445,360	207,900	64,680	2,044,800	1,137,098
1949	144,482,387	6,462,651	13,712,557	2,157,950	389,810	218,790	73,860	2,354,320	885,308
1950	147,958,578	7,287,324	14,840,945	2,142,170	391,570	266,620	54,410	2,423,530	694,386

1/ Sugar Branch, PMA. Refined and direct-consumption sugar, delivered weight. Includes deliveries for Armed Forces. 1942-44 includes imports of flavored and colored dirups from Cuba and Mexico. Adjusted for net change in invisibles. (See Table 35, p. 174)

2/ Reports of corn sugar refiners to Sugar Branch, PMA. Includes intra-company transfers; excludes small quantities of household-size packages.

3/ Reports of sales by corn refiners to Price-Waterhouse, distributed through Grain Branch, PMA.

4/ Source: Sugar Branch, PMA., See Table 36, p. 175.

dextrose in 1949-50 were above those prevailing during the wartime period. Dextrose sales slumped precipitously during late 1947 (immediately after sugar rationing to industrial users was discontinued) and early 1948, but had recovered significantly by the summer of 1948. Sales of this sweetener during 1950 were 7.3 million bags (100-pound units) or 300.0 percent of the 1935-39 average.

Per Capita Sweetener Usage - In Table 2, comparison is made of the relative per capita usage of sugar, corn sirup and dextrose from 1935 through 1950. Total primary sweetener usage per capita has increased from 106.6 pounds per capita, 1935-39, to 109.6 pounds (dry basis) during 1950. Per capita dextrose distribution has more than doubled and per capita corn sirup distribution has increased from 6.5 pounds to 8.1 pounds (dry basis). Conversely, per capita sugar distribution has decreased since the pre-war period. Clearly, from the standpoint of the individual consumer, total sweetener consumption has increased since the pre-war period. However, corn sweeteners have replaced sugar in foods to the extent that per capita sugar consumption has slightly decreased. The increase in per capita corn sweetener usage is explained by the expanded industrial production of prepared foods containing sweeteners in the past fifteen years.

Total Industrial Usage of the Primary Sweeteners

Industry's Share of Total Sugar Distribution - Since the purpose of this study is a comparison of the use of sugar and corn sweeteners in processed food products, the relative importance of the principal sweeteners can be better determined by excluding from total sweetener usage the quantities of sugar used for direct consumption by households, restaurants, and institutions. Practically all the dextrose and corn sirup is used in processed foods. Figure 4 presents the relative usage of sugar by industry and other users for the years 1935, 1939, and 1950. It is estimated from Census data available, that in 1935, almost three-fourths of the sugar consumed in this country was distributed directly to households, restaurants, and institutions, while in 1939, only two-thirds of the sugar consumed was distributed to this group. During the war, the industrial user became the important consumer of sugar and remained so after the war, consuming an estimated 51 percent of all sugar distributed in 1950.

As shown in Figure 5, of the total volume of sugar delivered for domestic consumption in 1950 by primary distributors, approximately 41 percent was delivered directly to wholesale grocers, jobbers, and sugar dealers; 16 percent to retail grocers, chain stores, and super markets, and 43 percent to industrial users, hotels, restaurants, and institutions. Almost all of the sugar delivered directly to the retail category is crystalline sugar in consumer-size packages and moves on to the household consumer. The balance of household purchases (24 percent) comes from the wholesalers via the retailer.

The percentage shown for sugar moving from wholesalers to retail grocers is exclusive of the quantities of sugar used by the latter in the manufacture of food products. Insofar as chain store retailers

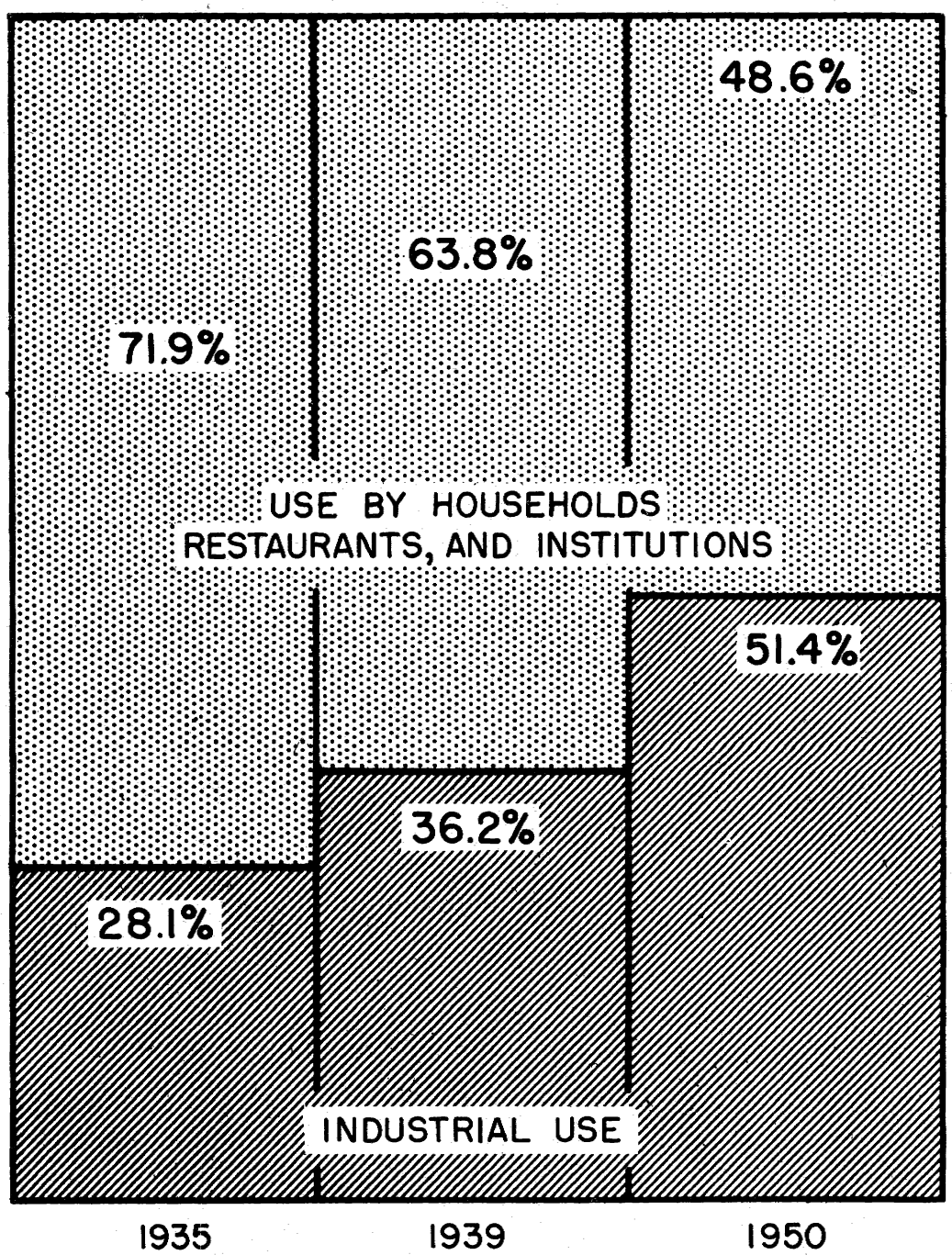

Figure 4.--Estimated quantities of sugar used by industry and other consumers, as a percentage of total sugar available for domestic and military use, United States, 1935, 1939, and 1950.

Source: Appendix, Table 42.

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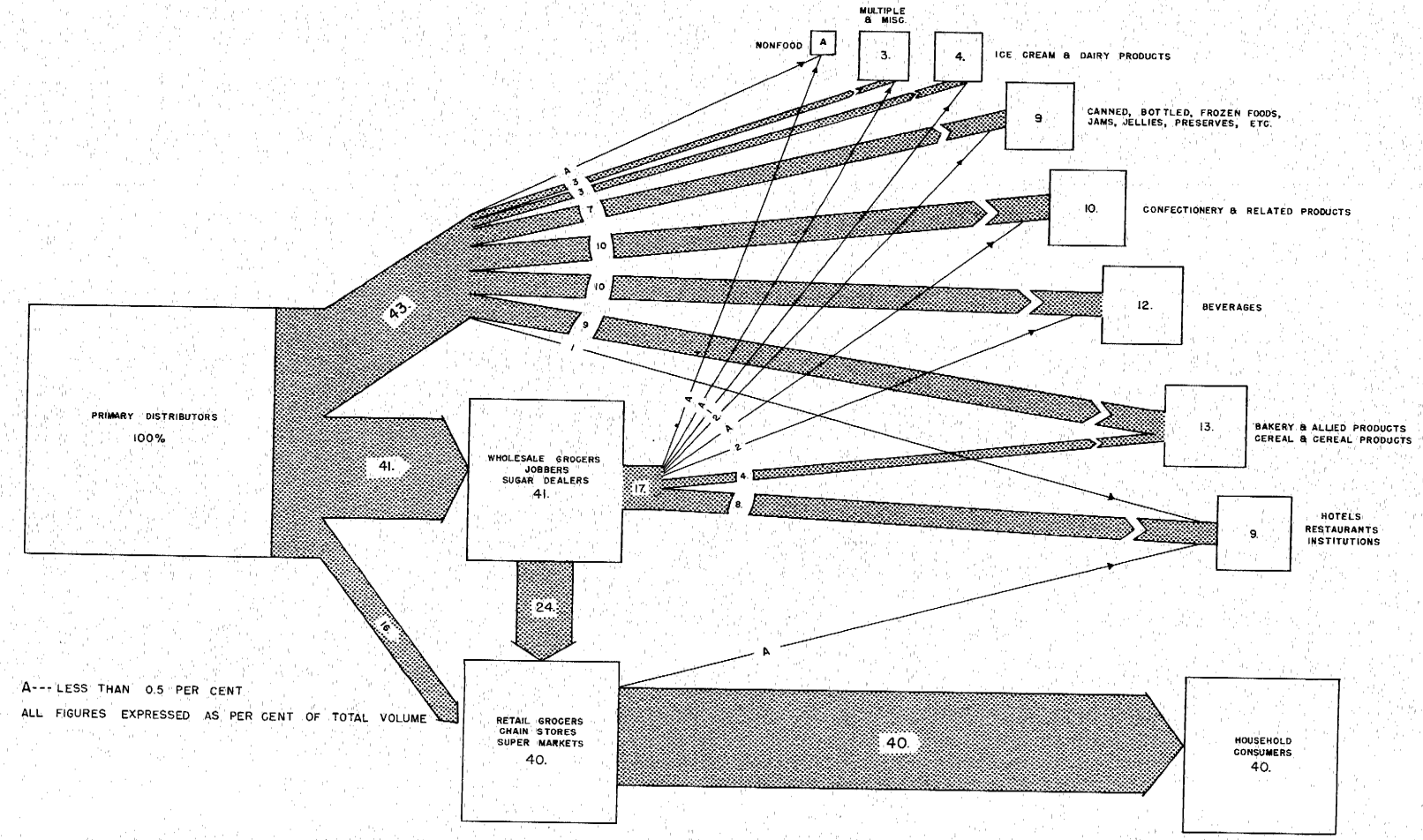

Figure 5.--Channels of Sugar Distribution for Domestic Consumption from Primary Distributors to Household Consumers and Other Users, United States, 1950.

Table 2 - POPULATION 1935-1950, AND PER CAPITA SWEETENER CONSUMPTION IN THE CONTINENTAL UNITED STATES, 1935-1950

Calendar Year	Population 1/ (thousands)	Sweetener consumption per capita, in pounds					
		Sugar 2/	Dextrose	C. S. U. 3/		Total consumption including	
				Wet basis	Dry basis	C.S.U. Wet	C.S.U. Dry
1935	127,250	98.8	1.3	7.2	5.8	107.3	105.9
1936	128,053	100.0	1.7	8.8	7.1	110.6	108.8
1937	128,825	98.1	1.9	7.8	6.3	107.8	106.3
1938	129,825	97.2	2.0	8.0	6.4	107.2	105.6
1939	130,880	96.4	3.2	8.3	6.7	107.9	106.3
5 yr. Aver.	128,967	98.1	2.0	8.0	6.5	108.1	106.6
1940	131,970	94.9	2.7	8.2	6.6	105.8	104.2
1941	133,203	105.8	3.9	9.1	7.3	118.8	117.0
1942	134,665	91.2	4.6	14.9	12.0	110.6	107.7
1943	136,497	86.9	4.4	13.1	10.5	104.4	101.8
1944	138,083	97.6	4.0	13.1	10.5	114.7	112.1
1945	139,586	81.4	4.1	13.1	10.5	98.6	96.0
1946	141,229	74.5	3.9	12.5	10.0	90.9	88.4
1947	144,002	92.1	4.5	13.5	10.8	110.1	107.4
1948	146,571	97.2	4.2	8.8	7.1	110.2	108.5
1949	149,215	96.8	4.3	9.2	7.4	110.3	108.5
1950 4/	151,772	96.8	4.7	10.1	8.1	111.6	109.6

1/ Official estimates of Bureau of the Census; includes military personnel.
2/ Beet and cane sugar, as produced; adjusted for invisible stocks and including deliveries to armed forces.
3/ Corn Sirup Unmixed.
4/ Preliminary

purchase sugar for the manufacture of food products, they are covered by the 17 percent delivered to industrial users and hotels, restaurants, and institutions by wholesalers.

The trend which has established industry as that segment of our economy using the largest proportion of sugar distributed in the United States, explains in large measure the decrease in per capita consumption of sugar. The household consumer, to whom only negligible quantities of corn sweeteners are sold, now purchases a larger proportion of his sugar in the form of processed foods produced by industries which use not only sugar but corn sweeteners as well. Thus, it is that dextrose and corn sirup consumption relative to sugar consumption has increased in the total economy. Paradoxically, industrial usage of corn sweeteners relative to industrial sugar usage has not increased since 1935-39 and this is discussed in the following section.

Trends of Total and Relative Sweetener Usage by Industry - Figure 6 presents the general trend of primary sweetener usage by industry in the past 16 years. An increased usage is noted between 1935 and 1950 for each type of sweetener, sugar usage having increased from 35 million to more than 75 million bags, corn sirup usage from 9.1 to 14.8 million units (wet basis), and dextrose usage from 1.7 to 7.3 million bags. As shown, dextrose usage has increased relatively more than that of either sugar or corn sirup and sugar usage relatively more than that of corn sirup.

A clearer picture of the relative importance of the individual primary sweeteners to industry is presented in Figure 7. In 1950, of the total primary sweetener usage by industry, sugar represented 77.3 percent, dextrose 7.5 percent, and corn sirup 15.2 percent. Census and Sugar Branch data available for pre-war years and for 1950, respectively, indicate a slight increase of sugar usage relative to total corn sweetener use.

The use of dextrose relative to total sweeteners used by industry has increased from 3.6 percent to 7.5 percent from 1935 to 1950. During the war, the use of dextrose was an even higher percentage of total sweetener use by industry, equaling almost 8 percent in 1942.

Corn sirup, unmixed, represented 20 percent of total sweetener use in 1935. Except for the war period, total usage of corn sirup relative to total sweetener usage by industry has declined and now equals only 15 percent of total sweetener usage. During the war, industry fell back upon this sweetener as a primary substitute for sugar to such an extent that the usage of corn sirup equaled as much as 26 percent of the total in one year, 1942.

Industrial Usage of Sweeteners, by Type of Sweetener, 1935-50

Sugar - The baking and cereal products industry has been and remains the largest industrial user of refined sugar. Sugar usage by manufacturers in this category equaled 13.2 million 100-pound units in 1939 and increased to about 19.5 million units in 1950. (See Figure 8)

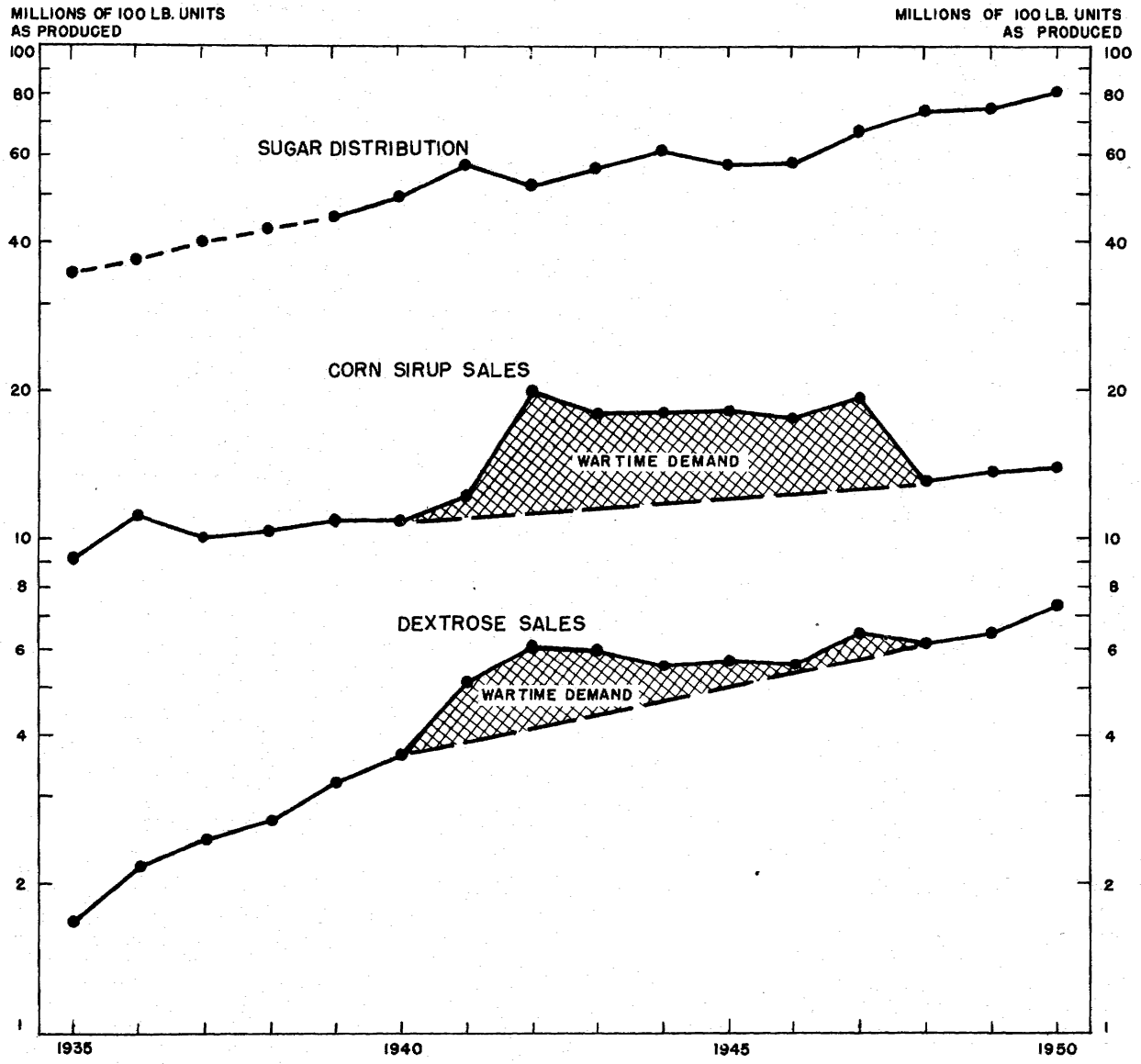

Figure 6.--Quantities of sugar, corn sirup, and dextrose used in industry, United States, 1935-50.

Source: Appendix, Table 60.

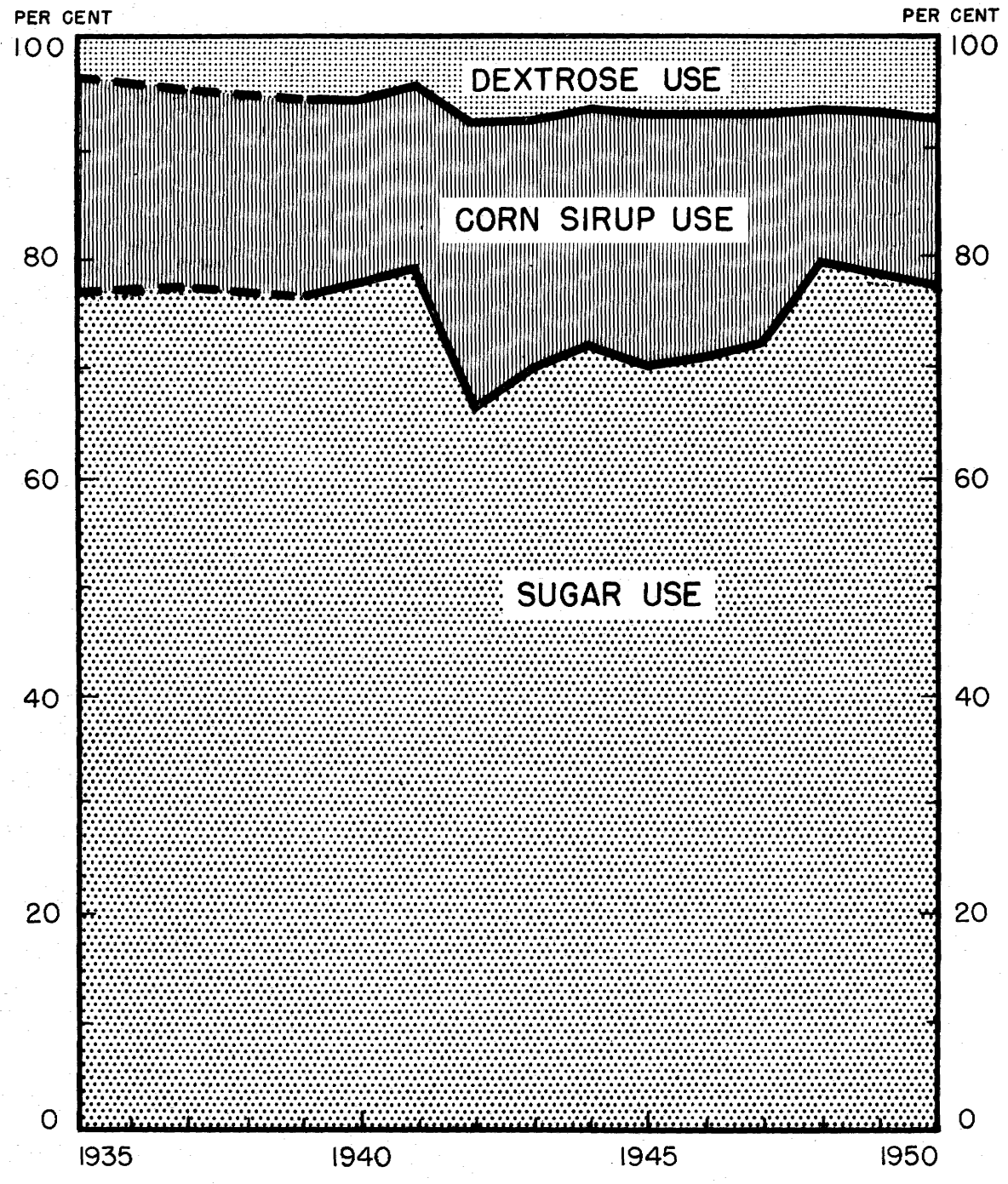

Figure 7.--Use of sugar, corn sirup, and dextrose, as a percentage of total primary sweetener use, by industry, United States, 1935, 1937, 1939-50.

Source: Appendix, Table 60.

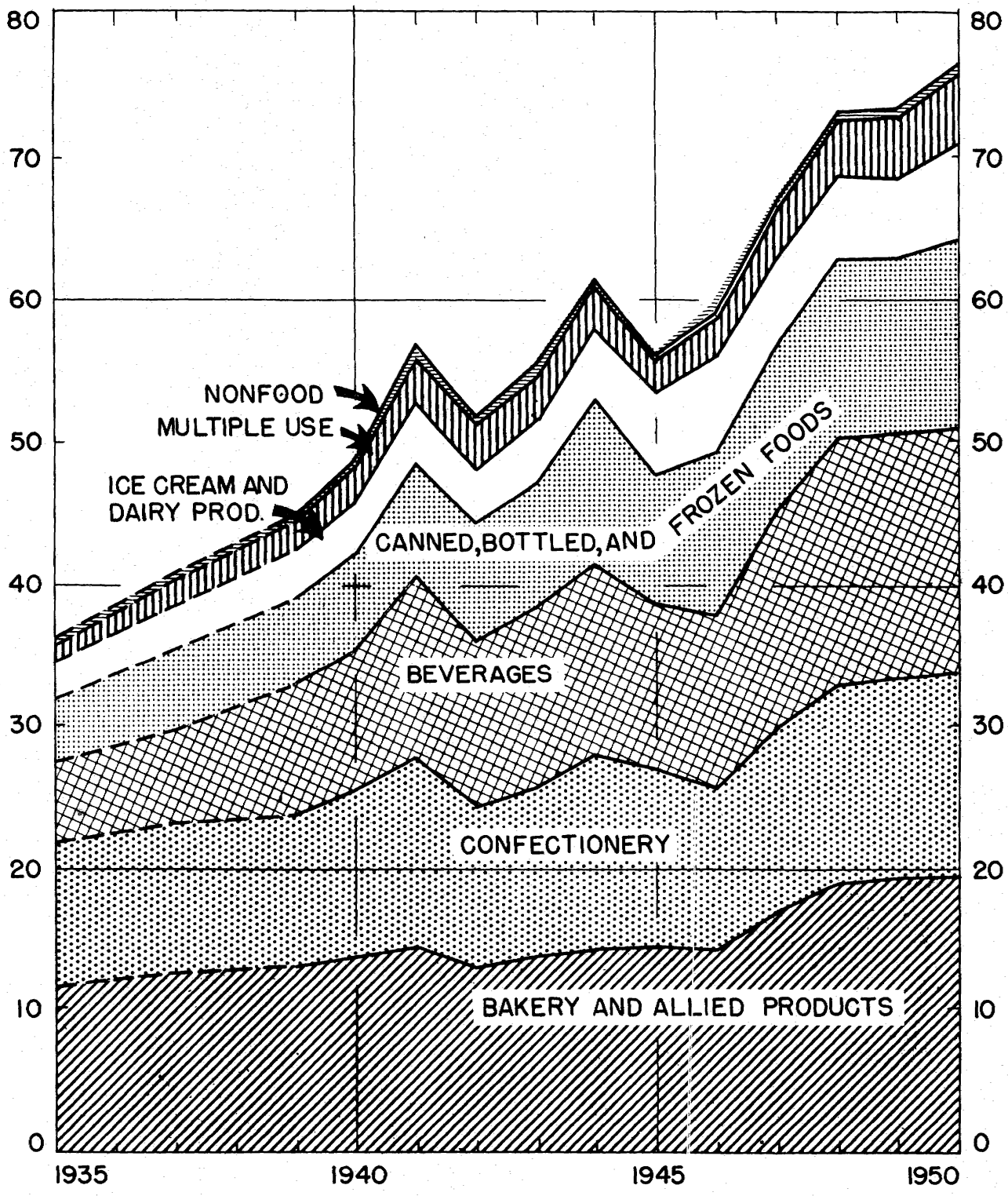

Figure 8.--Use of sugar, according to industrial groups, United States, 1935-50.

Source: Appendix, Table 47.

The beverage industry which used an estimated 17.0 million units in 1950, ranks second in importance. Although the confectionery and related products industry was a larger sugar user than the beverage industry prior to World War II, it used two million units less than the beverage industry in 1950. Manufacturers in the category "Canned, bottled, frozen foods, etc." have greatly increased their sugar usage since pre-war and used an estimated 13.3 million units in 1950. As shown in Figure 8, the above four categories used 64.4 million 100-pound units of sugar in 1950, or more than 85 percent of all sugar consumed by industry.

Although the baking and confectionery industries have increased their sugar usage since 1935-39, their usage as a percent of total industrial sugar usage has declined since pre-war. In 1935, the two categories together used 62 percent of all sugar consumed by industry; by 1950, their usage had dropped to less than 46 percent of the total. The manufacturers in the combined categories of "Beverages" and "Canned, bottled, frozen foods, etc." increased their share from 26 percent of the total in 1935 to 40 percent in 1950.

In 1950, as shown in Figure 9, total industrial usage of sugar was 84 percent greater than in the 1935-39 period. While all categories of sugar users increased their usage over pre-war, the most significant increases are noted in the categories "Beverages", "Canned, bottled, frozen foods, etc." and "Multiple and all other food uses." The sugar usage by the ice-cream and dairy products industry increased in slightly greater proportion than total industrial usage while the sugar usage of bakers and confectioners showed a less proportionate increase than did other industries. Nevertheless, bakers in 1950 used 156 percent as much and confectioners 138 percent as much sugar as they used during the period 1935-39.

Dextrose - The baking and cereal products industry is by far the largest purchaser of dextrose, using 4.2 million 100-pound units, or 58 percent of the total dextrose sold in 1950 (See Figure 10). The confectionery industry, second largest purchaser of dextrose in 1935, now exceeds in dextrose usage only the ice cream and dairy products industry. In contrast, the manufacturers in the categories "Beverages" and "Canned, bottled, frozen foods, etc.", which together used only 186 thousand units of dextrose in 1935, expanded their usage during the World War II control period and now use 1.6 million units, or more than 22 percent of total dextrose sales in 1950. The ice cream and dairy products manufacturers, like confectioners, used much more dextrose in 1950 than before the war, yet purchased a smaller percentage of the total dextrose sold to industry.

The use of dextrose by all industries in 1950 equaled 300 percent of pre-war usage (See Figure 11). The greatest increases in dextrose usage occurred in 1941 and 1942; it has been more gradual since then. The greatest increase in dextrose usage is noted in the category "Multiple and all other food uses", which purchased 678 percent as much dextrose in 1950 as in the pre-war period. The categories "Non-food products" and "Canned, bottled, frozen foods, etc." follow in order of increased

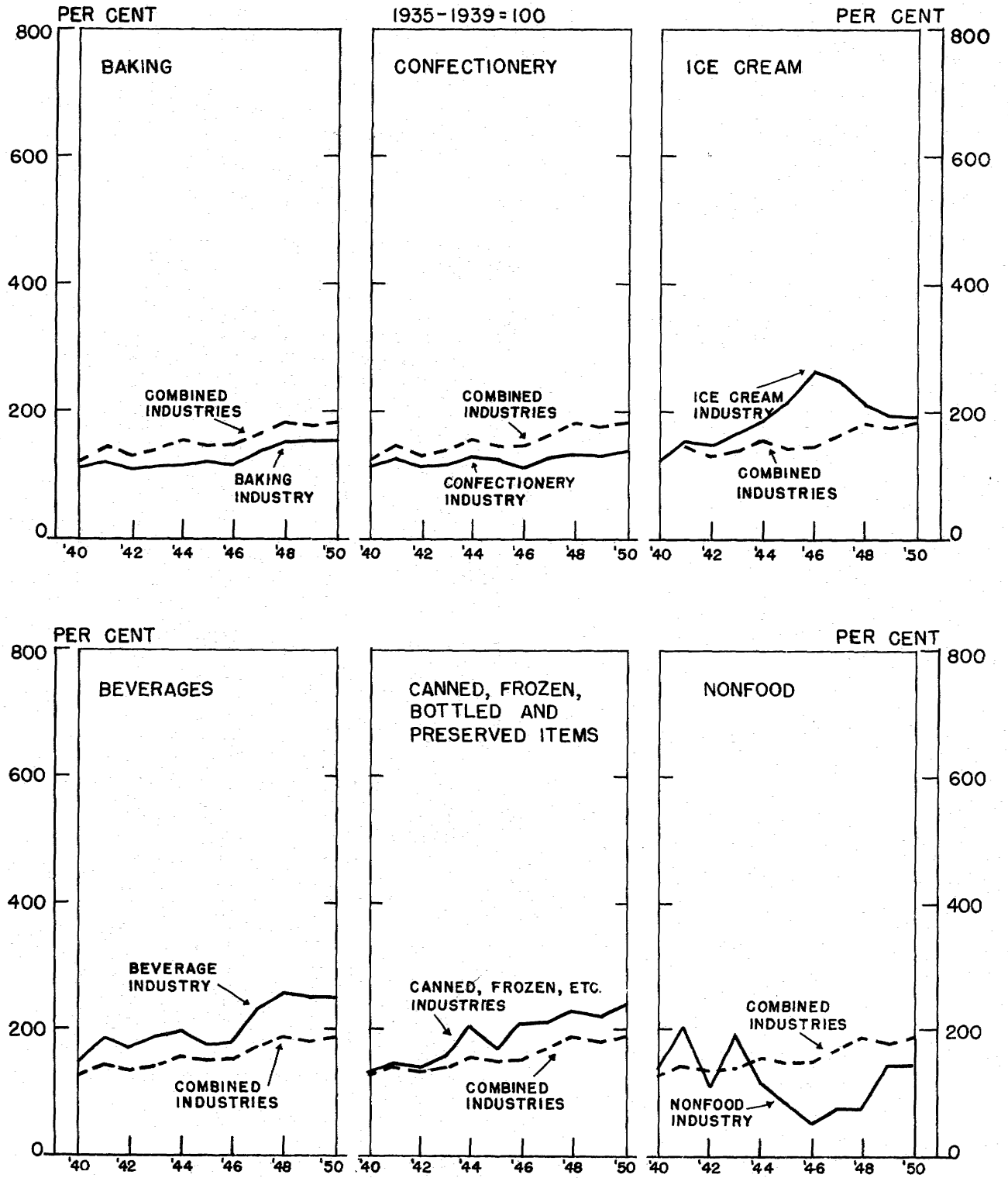

Figure 9.--Index numbers of use of sugar by specified industries, compared with use by all industries combined, 1940-50.

Source: Appendix, Table 51.

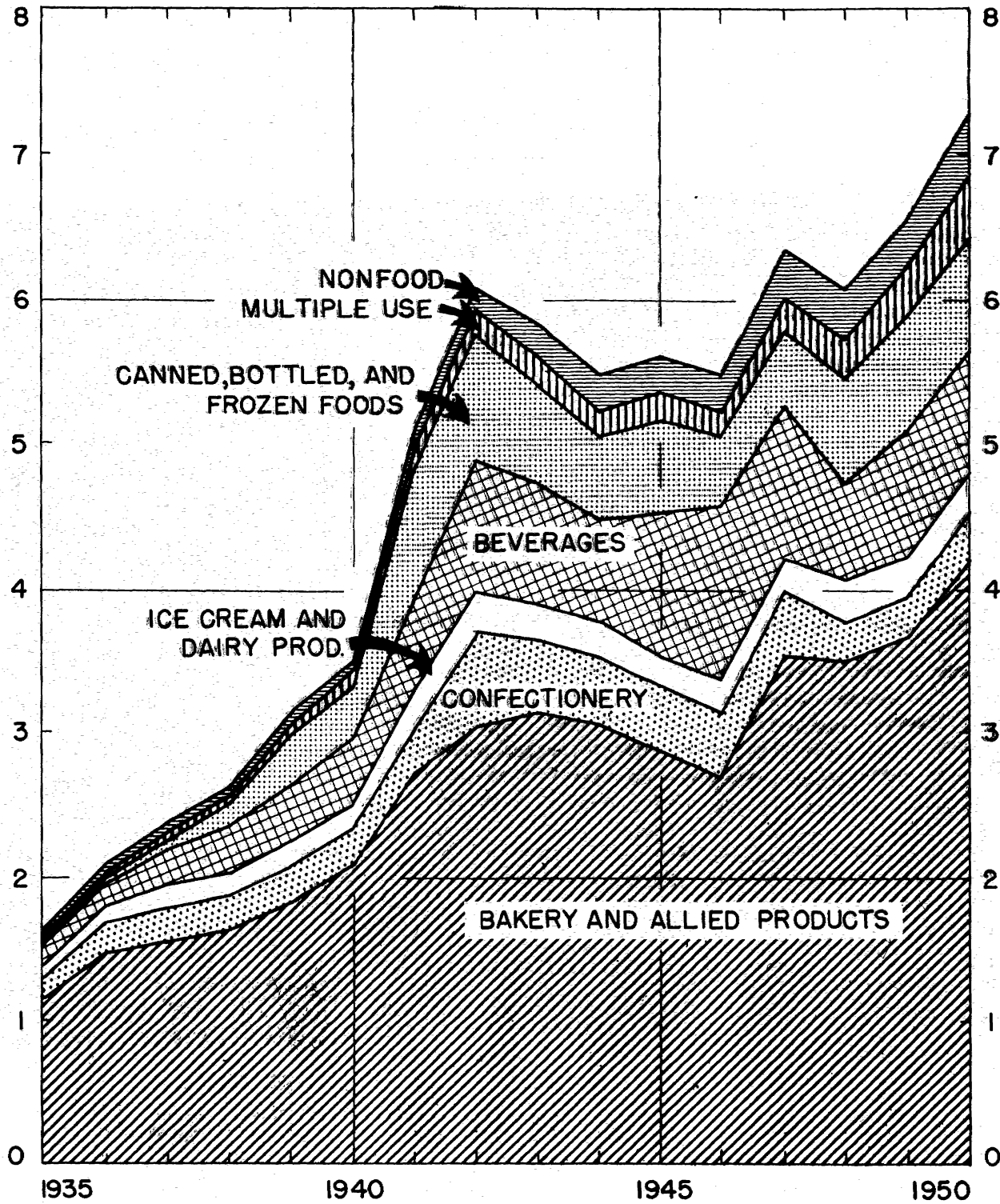

Figure 10.--Use of dextrose, according to industrial groups, United States, 1935-50.

Source: Appendix, Tables 52 and 53.

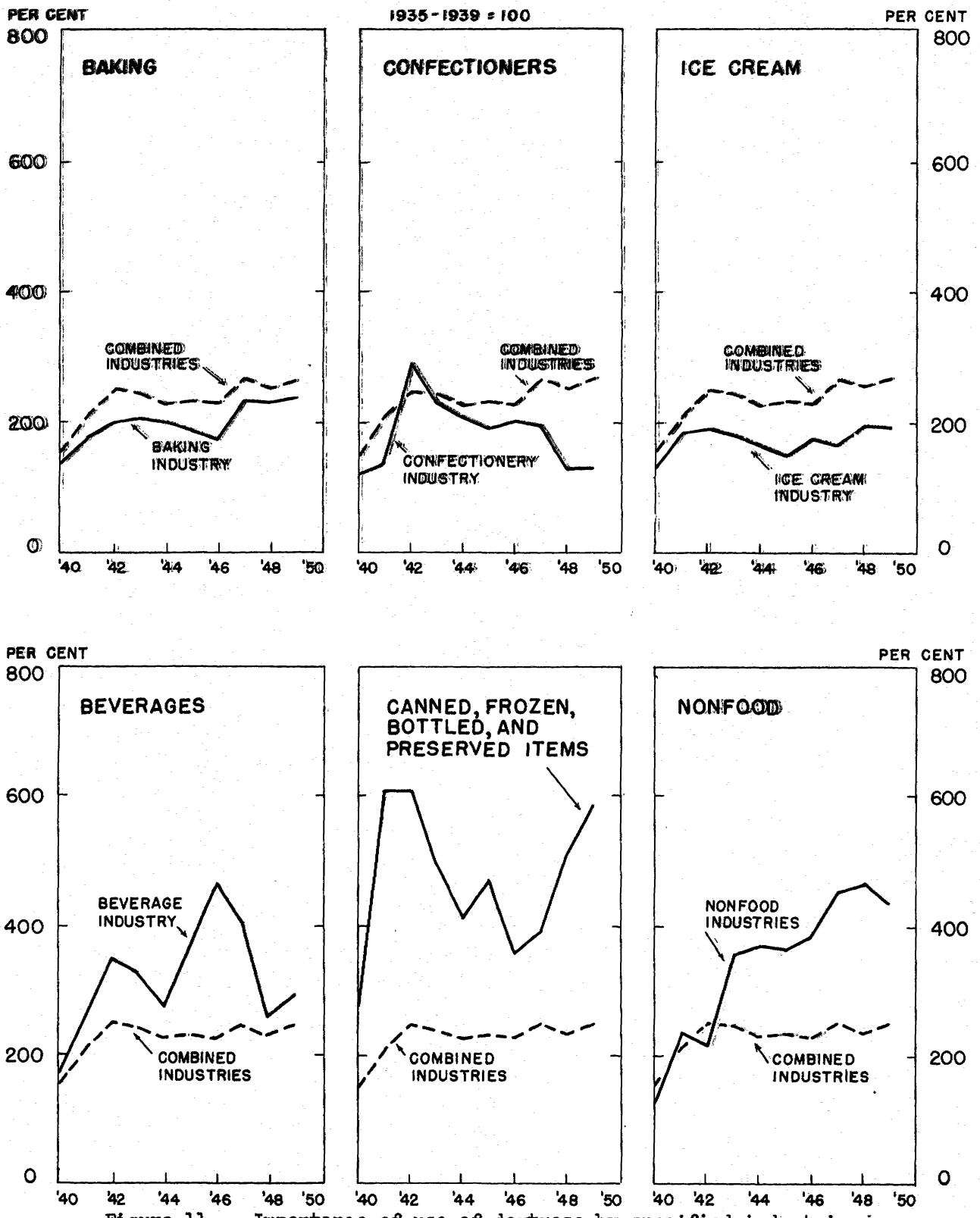

Figure 11. - Importance of use of dextrose by specified industries, compared with total industry use, 1940-50.

Source: Appendix. Tables 52 and 53.

usage. Usage by the beverage manufacturers, which in 1946 increased to 463 percent of pre-war usage, declined somewhat in 1948, and in 1950 equaled 321 percent of pre-war. The remaining categories increased their usage but to a lesser extent than the four categories above.

Corn Sirup Unmixed - The "Confectionery and related products" group is the predominant user of corn sirup, purchasing 7.6 million 100-pound units in 1950, or 51 percent of the total corn sirup sold. (See Figure 12) The blended sirups industry 4/, which used almost 29 percent (3.1 million units) of the corn sirup sold during the pre-war period, increased its purchases during the World War II control period to more than 6.8 million units in 1942, the peak year. However, sales of blended sirups collapsed during 1947, and the blended sirups industry used less corn sirup in 1950 than was used in 1939 and only 23 percent of total corn sirup usage. Purchases of corn sirup by manufacturers in the remaining categories are small compared with those of confectioners and sirup blenders and, except for the baking industry, no other category purchased as much as seven percent of the total in any year of the period 1935-50. 5/

Relatively little change in corn sirup usage took place prior to 1942 except in the ice cream industry. World War II gave great impetus to sales of corn sirup to all types of buyers except brewers. (See Figure 13) Even though purchases of corn sirup declined generally following the end of war controls in 1947, the overall usage of corn sirup in 1950 equaled 143.5 percent of prewar usage.

The greatest variation in corn sirup usage has occurred within the ice cream and dairy products industry. In 1942, the manufacturers in this category used 87 times the corn sirup used during pre-war. Even though their usage has declined since the war control period, and equals less than 3 percent of total corn sirup usage, these manufacturers used in 1950 more than 30 times their pre-war usage of corn sirup. Similarly, the manufacturers of soft drinks, who used negligible quantities of corn sirup during 1935-39, used 322 thousand units in 1942. However, unlike ice cream manufacturers, the soft drink manufacturers have used only relatively minor quantities of corn sirup since the war.

Appreciable increases in corn sirup usage are noted in one other category, "Canned, bottled, frozen foods, etc.". Usage by these manufacturers equaled 568 percent of pre-war in 1950. Only one type of

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4/ For dextrose and sugar usage, this industry is included under the category "Multiple and all other food uses."

5/ There has been, in recent years, a growing interest in the use of corn sirup solids, particularly within the ice cream industry. Figures on solids usage are not available and are not included in the corn sirup figures of this chapter. However, the use of corn sirup solids is discussed in a subsequent chapter.

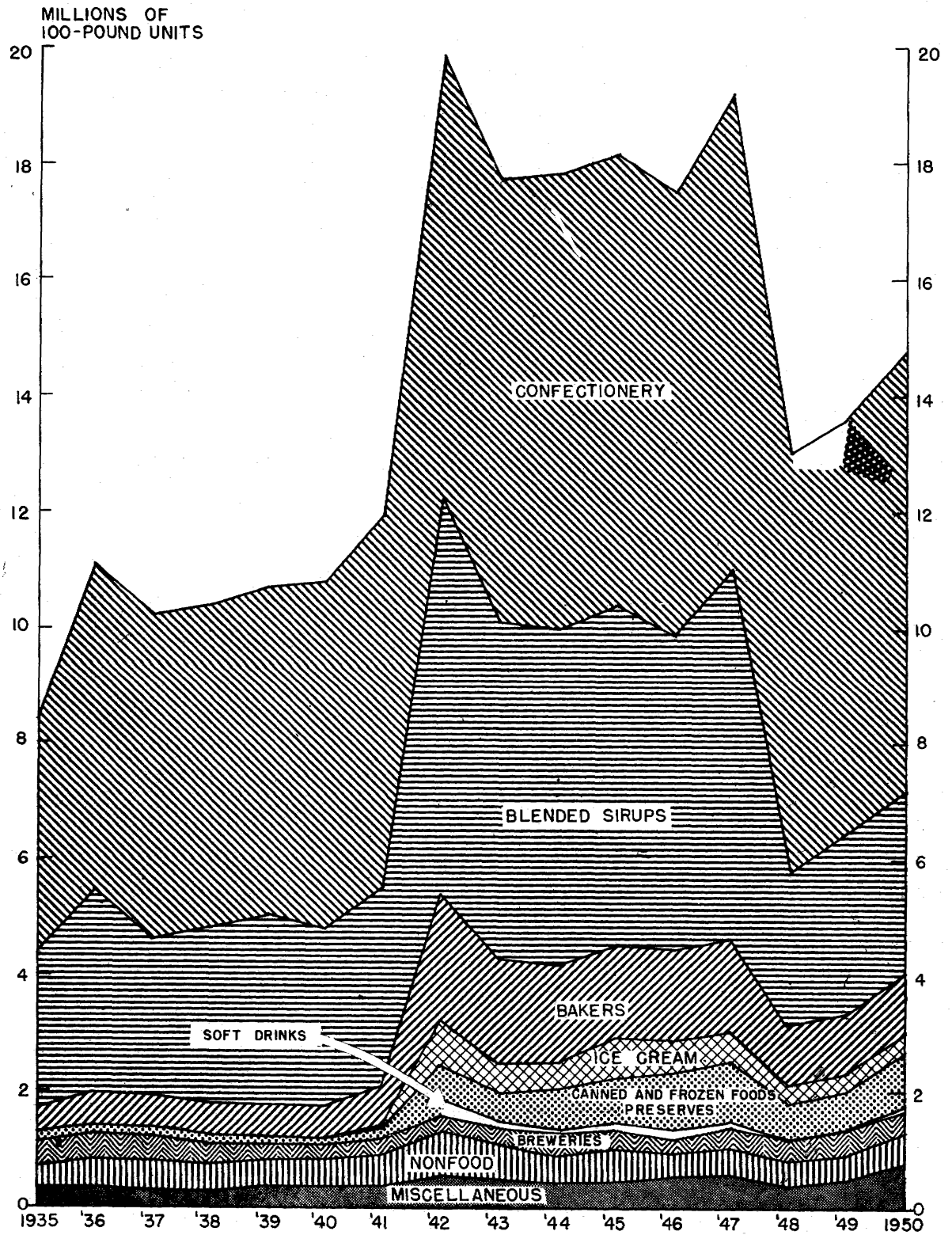

Figure 12.--Use of corn sirup by industrial groups, United States, 1935-50.

Source: Appendix, Tables 56 and 57.

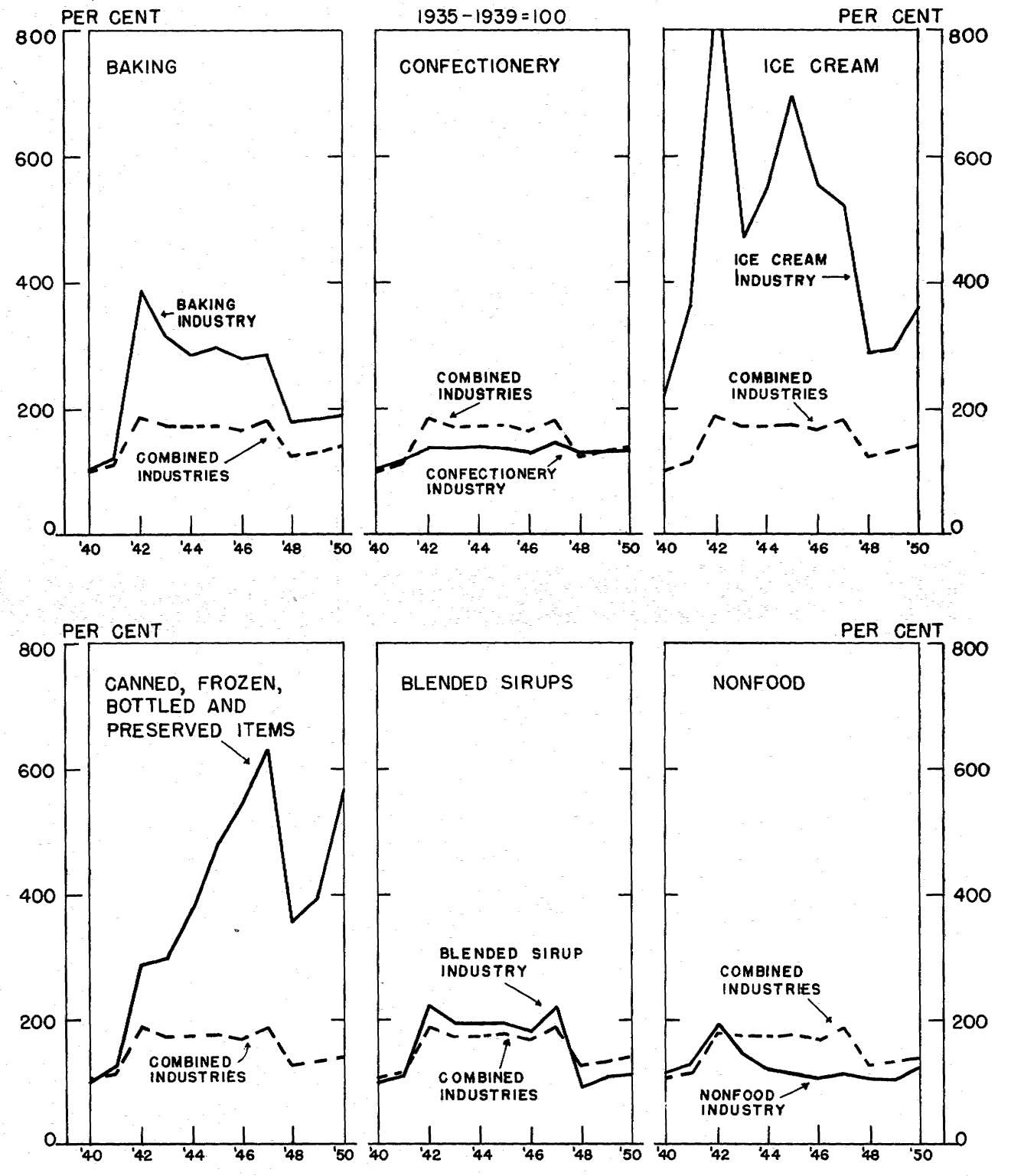

Figure 13.--Importance of use of corn sirup by specific industries compared with total industry use, 1940-50.

Source: Appendix, Table 58.

manufacturer, the brewer, showed no increase of corn sirup usage in the post-war period as compared with pre-war. His usage in 1950 equaled 99 percent of 1935-39 usage.

Industrial Usage of Sweeteners, by Type of Industry

Bakery and Allied Products - The baking industry during the 16-year period (1935-50) has relied heavily on sugar as the chief sweetening ingredient in its products. As shown in Table 3, sugar usage for this period has averaged 15 million 100-pound units, or 79 percent of total sweetener usage. Prior to the war, sugar represented between 84 and 88 percent of total primary sweetener usage. In 1950, the industry used 19.5 million units of sugar, 79 percent of total sugar, corn sirup and dextrose used. During the war years, sugar usage was smaller than in either of these periods due to the short supply situation. The low point in sugar usage (as a percent of total sweetener usage) occurred in 1942 when corn sweetener purchases represented 29 percent of total sweetener usage. In that year the sharp rise in corn sirup purchases was commensurate with the fall in sugar usage. Since that year, there has been a decline in corn sirup purchases and, as a percentage of total sweetener usage, corn sirup purchases by the industry have fallen almost to 1939 levels. In 1950, the industry used slightly more than 1.0 million units of corn sirup representing 4.3 percent of total sweetener usage.

Dextrose usage by the baking industry has increased steadily. Except for the period 1944-46 when slight decreases in usage occurred, the quantity of dextrose used has increased year after year. From an average usage of 1.5 million units in 1935-39, the baking industry usage increased to 4.2 million units of 100 pounds in 1950. Not only has dextrose usage increased by absolute quantities, its usage by the industry has increased relative to sugar usage. As a percentage of total sweetener usage, dextrose purchases have increased from less than 11 percent in 1935-39 to 17 percent in 1950. Combined dextrose and corn sirup usage represented 21 percent of total sweetener usage by manufacturers of bakery and allied products in 1950.

Confectionery and Related Products - The confectionery industry used approximately the same relative quantities of sugar, dextrose and corn sirup during 1948-1950 that they used during the pre-war period, 1935-39 (See Table 4). Sugar usage increased from 10.9 million 100-pound units in 1939 to 14.7 million units in 1950 and equaled approximately 65 percent of total sweetener usage in each year. Dextrose purchases are small and have equaled less than two percent of total sweetener usage during any normal period of supply. Corn sirup usage increased from 5.7 million units in 1939 to 7.6 million units in 1950, approximating one-third of total sweetener usage in both years. With the exception of the war-time rationing period, the confectionery industry has shown a fairly stable relationship in sweetener usage, continuing to use in 1948-50 the same relative quantities of each type of sweetener as in the pre-war years.

Table 3 - Bakers' Usage of Sugar, Dextrose and Corn Sirups, United States, 1935-50

(Thousands of 100-pound units)

Year	Sugar	Percent of Total	Dextrose	Percent of Total	Corn Sirups	Percent of total	Total
1935	11,500	87.6	1,162	8.8	471	3.6	13,133
1936	n.a.	-	1,472	-	574	-	-
1937	12,700	85.8	1,551	10.5	550	3.7	14,801
1938	n.a.	-	1,625	-	560	-	-
1939	13,180	84.6	1,816	11.7	580	3.7	15,576
1940	13,830	83.7	2,119	12.8	580	3.5	16,529
1941	14,670	81.2	2,720	15.0	678	3.8	18,068
1942	12,900	71.2	3,045	16.8	2,156	12.0	18,101
1943	13,830	73.9	3,139	16.8	1,739	9.3	18,708
1944	14,210	75.3	3,052	16.2	1,615	8.5	18,877
1945	14,390	76.0	2,888	15.2	1,667	8.8	18,945
1946	14,110	76.9	2,684	14.6	1,555	8.5	18,349
1947	16,920	76.6	3,569	16.2	1,592	7.2	22,081
1948	18,800	80.7	3,504	15.0	1,010	4.3	23,314
1949	19,460	80.7	3,650	15.1	1,007	4.2	24,117
1950 1/	19,460	78.7	4,205	17.0	1,058	4.3	24,723

n.a. - not available
1/ Preliminary

Table 4 - Confectionery and Related Products Usage of Sugar, Dextrose and Corn Sirup, United States, 1935-50

(Thousands of 100-pound units)

Year	Sugar	Percent of Total	Dextrose	Percent of Total	Corn Sirups	Percent of total	Total
1935	10,370	68.0	161	1.0	4,724	31.0	15,255
1936	n.a.	-	222	-	5,647	-	-
1937	10,750	64.9	231	1.4	5,587	33.7	16,568
1938	n.a.	-	238	-	5,606	-	-
1939	10,900	64.7	270	1.6	5,671	33.7	16,841
1940	11,870	65.6	269	1.5	5,947	32.9	18,086
1941	13,360	66.3	311	1.5	6,496	32.2	20,167
1942	11,680	58.2	654	3.2	7,745	38.6	20,079
1943	11,960	59.0	521	2.6	7,786	38.4	20,267
1944	13,740	62.1	480	2.2	7,895	35.7	22,115
1945	12,520	60.6	438	2.1	7,716	37.3	20,674
1946	11,310	58.6	452	2.3	7,556	39.1	19,318
1947	12,990	60.0	447	2.1	8,189	37.9	21,626
1948	13,940	65.2	290	1.4	7,146	33.4	21,376
1949	14,030	65.1	291	1.4	7,221	33.5	21,542
1950 1/	14,690	65.0	323	1.4	7,596	33.6	22,609

n.a. - not available
1/ Preliminary

954135 O—51——4

The Beverage Industry - Sugar usage by the beverage industry almost quadrupled since 1935. As shown in Table 5, the industry has used sugar to the extent of 88 to 95 percent of total sweetener usage in its products from 1935 through 1950. Dextrose usage by the industry has increased to six times the 1935 usage in absolute quantities and to a much lesser extent as a percentage of total sweetener usage. Corn sirup purchases by the industry in 1950 approximated those of the pre-war period, but as a percentage of total sweetener usage, were less than 4/10 of pre-war usage.

The figures in Table 5 combine the sweetener usages of the alcoholic and non-alcoholic beverage industries. These combined figures require further explanation because of the uses made of specific sweeteners by individual segments of the industry. Manufacturers of soft drinks, extracts and flavored sirups use between 95 and 97 percent of all sugar consumed by the beverage industries, while brewers and other manufacturers of alcoholic beverages use practically all of the corn sirup and between 40-45 percent of the dextrose moving into the manufacture of beverages. The usage of corn sweeteners in alcoholic and non-alcoholic beverages is shown in Table 6.

Prior to World War II, corn sirup sales to soft drink manufacturers were negligible. Exigencies of the war induced many manufacturers to supplement their sugar rations with other sweetening agents in order to maintain volume of production. Thus, corn sirup was used in relatively large quantities until rationing was discontinued.

Dextrose sales to the beverage industry have increased tremendously since the pre-war period, primarily to soft drink manufacturers. Sales to alcoholic beverage manufacturers have increased 77 percent since the 1935-39 period, while sales to non-alcoholic beverage manufacturers in 1950 were more than 9 times those of the pre-war period.

Less than one-third of the total sweeteners used by the alcoholic beverage manufacturers in 1950 was sugar; the non-alcoholic beverage industry used approximately 97 percent sugar and 3 percent corn sweeteners.

Canned, Bottled, Frozen Foods, Jams, Jellies, Preserves, etc. - Total usage of sugar, corn sirup and dextrose by these manufacturers amounted to 15.1 million 100-pound units in 1950 and was more than twice as large as total usage in the 1935-39 period. In 1950, sugar represented 88.1 percent of total sweetener usage and dextrose and corn sirups usage amounted to 5.3 and 6.6 percent, respectively, of the total. The quantity of corn sweeteners used was almost six times that used in 1935-39 and sugar usage was more than double that of the pre-war period. However, 1950 sugar usage represented a slightly smaller percentage of total sweetener usage and corn sweeteners a larger percentage than in the 1935-39 period. (See Table 7)

Table 5 - Beverage Industry Usage of Sweeteners, United States, 1935-50

(Thousands of 100-pound units)

Year	Sugar	Percent of Total	Dextrose	Percent of Total	Corn Sirups	Percent of Total	Total
1935	4,580	89.4	140	2.7	403 1/	7.9	5,123 1/
1936	n.a.	-	169	-	453	-	-
1937	6,450	90.4	263	3.7	420 1/	5.9	7,133 1/
1938	n.a.	-	337	-	333	-	-
1939	9,250	93.2	392	3.9	287 1/	3.9	9,929 1/
1940	10,000	93.5	445	4.2	243 1/	2.3	10,688 1/
1941	12,800	93.1	672	4.9	281 1/	2.0	13,753 1/
1942	11,780	88.5	913	6.9	609	4.6	13,302
1943	12,800	91.3	846	6.0	375	2.7	14,021
1944	13,460	92.1	720	4.9	439	3.0	14,619
1945	11,780	89.1	987	7.5	457	3.4	13,224
1946	12,240	88.2	1,207	8.7	434	3.1	13,881
1947	15,330	91.2	1,050	6.2	437	2.6	16,817
1948	17,210	94.5	677	3.7	330	1.8	18,217
1949	17,020	93.4	771	4.2	435	2.4	18,226
1950 2/	17,020	93.2	835	4.6	393	2.2	18,248

1/ Excludes small quantities of corn sirup used by soft drink manufacturers.
2/ Preliminary.

Table 6 - Corn Sweetener Sales to Alcoholic and Non-Alcoholic Beverage Manufacturers, United States, 1935-50

(Thousands of pounds)

Year	Corn Sirup Sales to Manufacturers of: Alcoholic Bev. 1/	Corn Sirup Sales to Manufacturers of: Non-alcoholic Bev. 2/	Dextrose Sales to Manufacturers of: Alcoholic Bev. 1/	Dextrose Sales to Manufacturers of: Non-alcoholic Bev. 2/
1935	40,293	n.a.	11,489	2,522
1936	45,267	n.a.	15,216	1,690
1937	41,964	n.a.	23,506	2,816
1938	33,294	n.a.	27,190	6,545
1939	28,668	n.a.	28,725	10,517
1940	24,328	n.a.	29,561	14,958
1941	28,079	3/ 234	39,928	27,291
1942	28,703	32,247	35,074	56,265
1943	31,871	5,655	38,816	45,750
1944	37,682	6,185	35,418	36,569
1945	37,416	8,326	38,491	60,204
1946	27,188	16,218	31,973	88,680
1947	35,975	7,719	42,117	62,913
1948	32,777	189	29,654	38,049
1949	42,948	542	4/ 34,700	4/ 42,400
1950	37,499	1,826	4/ 37,600	4/ 45,900

1/ Corn sirup sales reported only for breweries and brewery supply houses; dextrose sales include sales to brewers and to manufacturers of wines, cordials, etc.
2/ Corn sirup sales reported from 1942-50 for soft drink manufacturers only; dextrose sales include sales to soft drink manufacturers and manufacturers of extracts, flavored sirups, etc.
3/ Total of last 3 months of 1941.
4/ Estimated.

Table 7 - Use of Primary Sweeteners by Manufacturers of Canned, Bottled, Frozen Foods, Jams, Jellies, Preserves, etc., United States, 1935-50

(Thousands of 100-pound units)

Year	Sugar	Percent of Total	Dextrose	Percent of Total	Corn Sirups	Percent of Total	Total
1935	4,490	95.2	46	1.0	179	3.8	4,715
1936	n.a.	-	61	-	213	-	-
1937	5,980	96.0	75	1.2	175	2.8	6,230
1938	n.a.	-	152	-	155	-	-
1939	6,260	92.4	366	5.4	152	2.2	6,778
1940	7,010	92.5	386	5.1	179	2.4	7,575
1941	7,850	88.0	856	9.6	217	2.4	8,923
1942	7,380	84.3	860	9.8	517	5.9	8,757
1943	8,790	87.8	693	6.9	527	5.3	10,010
1944	11,310	90.1	578	4.6	666	5.3	12,554
1945	9,250	86.0	663	6.2	843	7.8	10,756
1946	11,400	88.8	499	3.9	944	7.3	12,843
1947	11,590	87.6	548	4.1	1,105	8.3	13,243
1948	12,720	90.4	722	5.1	625	4.5	14,057
1949	12,250	88.9	823	6.0	697	5.1	13,770
1950 1/	13,280	88.1	793	5.3	991	6.6	15,064

1/ Preliminary

The Ice Cream and Dairy Products Industry - Total sugar, corn sirup and dextrose usage by the ice cream and dairy products industry has doubled since the pre-war years and in 1950 equaled 6.3 million 100-pound units (See Table 8). The most pronounced increase in sweetener usage was in the industry's purchases of corn sirup which averaged 10.4 thousand units during the pre-war period and equaled 323 thousand units in 1950. Sugar remains the predominant sweetener used by the industry and represented more than 90 percent of total sweetener usage in 1950. However, it is significant that the industry now uses almost 10 percent corn sweeteners as compared with about five percent during the pre-war period.

Table 8 - Ice Cream Usage of Sugar, Dextrose and Corn Sirups, United States, 1935-50

(Thousands of 100 pound units)

Year	Sugar	Percent of Total	Dextrose	Percent of Total	Corn Sirups	Percent of Total	Total
1935	2,520	96.1	94	3.6	8	0.3	2,622
1936	n.a.	-	121	-	9	-	-
1937	3,180	94.9	160	4.8	10	0.3	3,350
1938	n.a.	-	172	-	11	-	-
1939	3,360	94.4	184	5.2	14	0.4	3,558
1940	3,740	94.7	185	4.7	24	0.6	3,949
1941	4,390	93.4	270	5.8	39	0.8	4,699
1942	3,830	76.3	277	5.5	915	18.2	5,022
1943	4,300	84.7	263	5.2	515	10.1	5,078
1944	5,050	85.8	239	4.1	596	10.1	5,885
1945	5,980	86.1	221	3.2	743	10.7	6,944
1946	6,820	88.9	258	3.4	593	7.7	7,671
1947	6,350	88.3	242	3.4	562	7.8	7,154
1948	5,990	91.0	289	4.4	305	4.6	6,584
1949	5,710	90.6	284	4.5	312	4.9	6,306
1950 1/	5,710	90.5	279	4.4	323	5.1	6,312

1/ Preliminary

FACTORS AFFECTING CHOICE OF SWEETENER

General Factors

There are many factors to be considered by a food processor before he chooses a sweetener or a combination of sweeteners to use in his product. Probably the three most prominent ones are differences in physical and chemical properties, relative prices, and Federal and State regulations governing types and/or amounts of sweeteners permitted in each unit of product. Detailed discussions of each of these factors are included in this chapter. There are, however, other factors which influence his choice of sweetener, a few of which are considered sufficiently important to warrant brief mention at this time.

Advertising and Sales Programs - Advertising and salesmanship no doubt are instruments used by the manufacturers and distributors of all types of sweeteners in attempts to influence a food processor's choice relative to type of sweetener used. It is well known that the manufacturers of corn sweeteners, especially of dextrose, usually have been more aggressive in their advertising campaigns than the sugar industry. Many wet corn milling companies also have employed a technical sales staff to aid in familiarizing buyers with the physical and chemical properties of the various corn sweeteners and to advise them regarding their proper usage. Aggressive efforts of the manufacturers of corn sweeteners has influenced to some extent the growing acceptance of these products in many fields of food processing.

In-Plant Handling Problems - Economies and conveniences of storage and use of sweetener at the plant often have a marked effect upon choice of sweetening ingredients. Such factors are prime considerations in choosing between dry and liquid sugar. One of the principal reasons for a food processor's using liquid sugar is the savings arising from economies and conveniences of storage and in-plant handling.

In many cases the added costs and production problems associated with storage and usage of more than one sweetener have a marked effect upon the type of sweetener used. For example, in most products corn sweeteners cannot be used satisfactorily as the sole sweetener but must be used in combination with sugar. On the other hand, sugar may be readily used as the only sweetener in these products. Therefore, a food processor who wishes to use a corn sweetener must maintain storage facilities for two sweeteners and must handle two sweeteners in the plant in making the product. This usually requires more storage space and adds to handling costs. It also enhances the possibilities of plant employees making formula errors in the production process.

The difficulties encountered in using two sweeteners are magnified when it is economical and convenient to use one in liquid form and the other is available only in dry form. For example, the most acceptable corn sweetener for a given use might be dextrose, which is available only in dry form, while economies could be effected by using liquid sugar. Or a corn sirup-sugar combination might be the preferred one in an area where liquid sugar was not available or uneconomical.

The size of a plant often has a marked effect upon the choice of a sweetener. In large-scale operations, there is more of an incentive to use more than one sweetener in order to effect small unit savings in production costs. On the other hand, in small operations the savings resulting from decreased ingredient costs may be offset by increased storage and handling costs. In general, the use of a combination of two or more sweeteners requires application of somewhat higher technical skills than when only one is used. Since larger companies usually are more likely to have personnel with such skills than small companies, there is relatively more of an incentive for the former to use corn sweeteners in combination with sugar. A substantial number of the small-scale companies contacted, in connection with this study, reported that they did not use corn sirup or dextrose primarily because of handling difficulties.

Physical or chemical properties of a sweetener which make it more difficult to handle than another sweetener often affect a food processor's decision relative to its use. For example, there is a certain element of danger of either liquid sugar or corn sirup resulting in stickiness of pipes under improperly controlled conditions. Such problems would not be encountered, of course, in using a dry sweetener, such as sugar or dextrose. Some companies, especially the smaller ones, would prefer to use a dry sweetener, usually at a somewhat higher unit cost, than to get involved with controlling pipe lines and storage tanks to avoid unsatisfactory flow or storage conditions.

Psychological Factors - Psychological factors are of considerable importance with many food processors in arriving at a decision as to what sweetener or sweeteners to use. In most food processing fields, the use of any corn sweetener relative to sugar is comparatively recent. Also, sugar in liquid form is a relatively new type of sweetener. Many industrial users who traditionally have used only dry sugar as a sweetening ingredient, are somewhat reluctant to change to liquid sugar or a combination of sugar and one of the corn sweeteners or, in the exceptional cases possible, to shift altogether to a corn sweetener. This is especially true if a manufacturer believes he has been very successful in arriving at a formula which results in a well-accepted product. He fears that altering his sweetening ingredients might affect adversely consumer acceptance of the product.

When the decision is one of whether or not to use a corn sweetener with or in place of sugar, many users consider what they believe will be the probable reaction of their customer relative to maintenance of quality standards. Simply because corn sweeteners are less expensive than sugar on a per-pound basis, there is a tendency on the part of some users to weigh heavily the probable impact of their use on consumer acceptance. This is especially true if the product in question is one requiring ingredient labeling.

Comparison of Certain Physical and Chemical Characteristics of Sugar and Corn Sweeteners

Differences in the chemical and physical characteristics of sweeteners influence a food processor's choice of these materials. The more important of these chemical and physical properties are: (1) Relative sweetness, (2) hygroscopicity (ability to absorb and retain moisture), (3) solubility and crystallization properties, (4) density of liquid sweeteners and moisture content of solid sweeteners, (5) preservative properties, and (6) flavor.

Regarding some of these characteristics, it is apparent that there are differences of opinion among scientific personnel. The brief discussion which follows is in no sense an attempt to contribute to technological research on the subject. It is intended only to point out that there are important differences in the physical and chemical properties of sweeteners and to indicate in general how these differences in properties influence commercial distribution and use. Reliance has been placed on the previous research of others and on discussions with persons who are currently engaged in technological research related to the subject. Although there has been no attempt to make an exhaustive study of all the differences between sweeteners, it is devised to call attention to those properties considered most important in affecting an industrial user's choice of sweetening agent.

Sweetness - Relative sweetness is a subject much debated among chemists and food technologists. It has been necessary for various reasons to modify the conclusions drawn from older studies, completed in the 1920's. One reason for this is that sweetening power has been improved as the result of the higher degree of refinement now characteristic of some of these sweeteners. Moreover, the best informed current opinion is that the degree of concentration chosen for comparison affects materially the relative degree of sweetness. Sweetness also is influenced by such factors as the temperature of the product in which sweeteners are being compared, the supplementary affects of two or more sugars, and the presence of acids, salts, flavoring materials and other non-sugar substances. There is no chemical test for sweetness; it must be tested by consumer taste, and perception to sweetness varies with individuals. For these various reasons, it is impossible to assign a specific sweetness value to each sweetener for all purposes. 6/

6/ A. T. Cameron, "The Taste Sense and the Relative Sweetness of Sugars and other Sweet Substances," Scientific Report Series No. 9, Sugar Research Foundation, Inc., New York, 1947.

The ratios of sweetness mentioned below are presented only to illustrate the broad range in relative sweetness reported by various research investigators.

In most studies of sweetening values, sugar has been used as the basis of comparison, its sweetening power being indicated as either 1.0 or 100 percent, and the relative sweetness of other materials has been stated in terms of sugar. The sweetest of the more commonly used materials are often considered to be honey and invert sugar. Completely inverted sugar is made up of half dextrose and half levulose. The levulose is much the sweeter of the two having been variously reported as 140 to 175 percent as sweet, while dextrose has been reported as 60 to 75 percent as sweet as sucrose. Many believe that on a moisture-free basis the product resulting from the inversion process is but little, if any, sweeter than the uninverted sucrose molecule. However, estimates of the sweetness of invert sugar run as high as 130 percent of that of sugar. 7/

Because honey usually contains a higher proportion of levulose than does commercial invert sugar, it is characteristically somewhat sweeter. Its higher density and resultant tendency to linger on the tongue give the impression that it is considerably sweeter than most sugar sirups.

Anhydrous dextrose is the sweetest of the corn sweetener group. The descending order of sweetness of the other corn sweeteners is: dextrose hydrate, high conversion corn sirup, regular corn sirup and low conversion corn sirup. "Corn sirup solids" is considered equivalent to regular corn sirup, when these are compared on a moisture-free basis. The most widely accepted ranges in sweetness for dextrose are 65 to 70 percent for dextrose hydrate and 70 to 75 percent for anhydrous dextrose.

Certain investigators 8/9/ have studied the sweetening values of sugar and the corn sweeteners at different concentrations, alone and in admixture, and for various uses. In ice cream, for example, it was found that when used with sugar, dextrose was considerably sweeter than would be indicated by its sweetening value in plain water solution. It was concluded by the investigators that from 20 to 25 percent of sugar in the ice cream mix could be replaced with dextrose without sacrificing the sweetness. An explanation of the supplemental effect upon total sweetness of sugar and a corn sweetener in the same solution

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7/ Erb, J. H. Sweetening Agents Suitable for Ice Cream, Chocolate Milk and Sweetened Condensed Milk. Ohio State Univ., Dept. Dairy Tech. p.2.

8/ Corbett, W. J. and Tracy, P. H. Dextrose in Commercial Ice Cream Manufacture. Ill. Agr. Exp. Sta. Bull. No. 452, March 1939, p. 375.

9/ Dahlberg, A. C. and Penczek, E.S. The Relative Sweetness of Sugars Affected by Concentration. N.Y. Agric. Exp. Sta. Tech. Bull. No. 258, April 1941, pp. 11-12. Dextrose and Corn Sirup for Frozen Desserts. N. Y. Agric. Exp. Sta. Bull. No. 696, Oct. 1940, p. 32.

or food product was offered as follows: "The sweetness of sucrose is quickly perceived, promptly reaches a maximum intensity, and then decreases. The sweetness of dextrose stimulates the taste sensory organs more slowly and reaches a maximum intensity later. Hence, the one sugar might be expected to supplement the other." The relative sweetness of corn sweeteners was found to be nearly twice as high a value in high concentrations as in low concentrations, and it was pointed out that many food products require a rather high concentration of sweetener content. The relative sweetness of dextrose (sugar as 100%) was reported to vary with the concentration and product use from 62 to 100; of high conversion corn sirup from 40 to 80; and that of regular corn sirup from 28 to 54.

The relative sweetness of corn sirup varies considerably with the degree of conversion. The usual hydrolysis process by which corn starch is converted into corn sirup may be controlled to give varying proportions of dextrose, maltose, higher sugars, and dextrins. The product may be further processed by a special acid and/or enzyme treatment to increase the proportion of dextrose and lower that of dextrin. In general, there are three commercial classifications of corn sirup, which vary according to dextrose equivalent (D.E.), the total reducing sugar content 10/ calculated as dextrose on a dry basis. These three classifications are low, regular or medium, and high-conversion, with the D.E. usually being from 28 to 33 for the low conversion type, from 40 to 43 for the regular conversion type and from 52 to 65 for the high conversion sirups. The approximate composition of corn sirup at any D.E. can be obtained by adding the figures indicated by each of the lines on figures 14 and 15. As the D.E. is raised, the dextrin content is lowered, with an accompanying increase in sweetness, since dextrin possesses no sweetness.

The various factors which govern sweetening power have definite significance in the processed foods industries. Corn sweeteners, apparently, are considered least sweet when used without sugar or in foods with low sugar content; therefore, greater amounts of corn sweetener must be used to provide comparable sweetness. However, when used in foods containing comparatively high sugar concentrations, the sweetness of dextrose and other corn sweeteners appears to be increased, and some authorities claim that in certain instances they may provide as much sweetness pound for pound as sugar.

For many purposes the degree of sweetness is a major factor influencing a food processor's choice of sweeteners. Sweetening ingredients, however, have many other characteristics which influence the desired results in a food product. In some foods, such as canned vegetables, sweetness itself is not desired, but the addition of a sweetener will bring out the flavor of -- or "season" -- a product more effectively than would otherwise be the case. On the other hand,

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10/ Reducing sugars are sugars like dextrose and levulose, which have the characteristic property, when tested in the chemical laboratory, of reducing a copper solution.

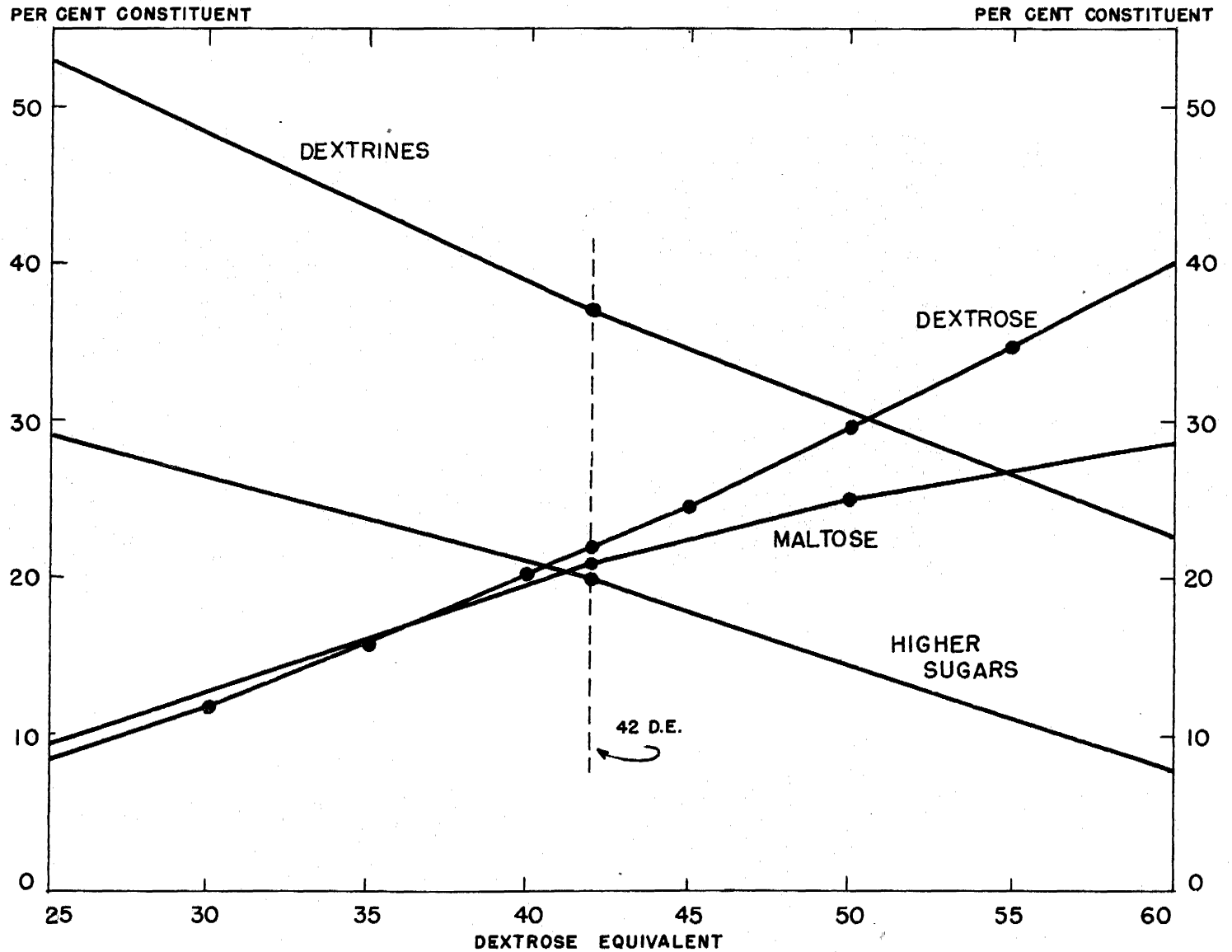

Figure 14.--Corn sirup analyses (carbohydrate dry substance).

Source: Appendix, Corn Industries Research Foundation.

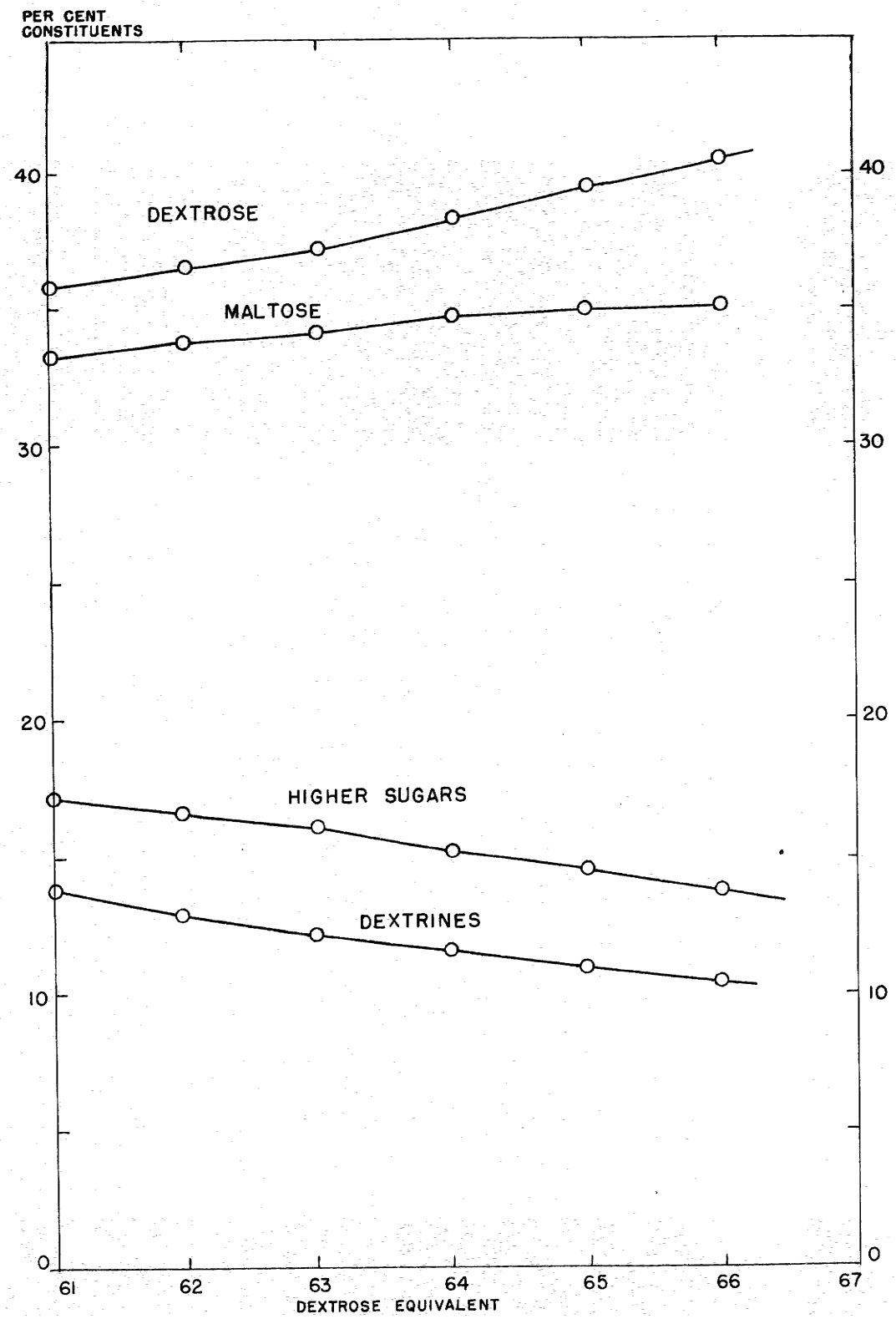

Figure 15.--Composition of acid-enzyme-converted corn sirup (dry substance basis)

Source: Appendix, Corn Industries Research Foundation.

an over-dose of sweetness is thought by many manufacturers to be just as detrimental to flavor as not enough sweetness.

A sweetener actually may be used to control sweetness as well as to provide an ample supply of sweetness. In an effort to achieve a proper balance of sweetness with the desired body or density, manufacturers of processed foods often use a combination of sweeteners. For example, a combination of sugar and corn sirup may be used as the packing medium for canned fruits to maintain the desired density without having excessive sweetness. The natural flavors of fruits which are bland in flavor are said by some canners to become masked by sweetness when sugar is the only sweetener used. Reducing the sweetness merely by lowering the quantity of sugar used may result in too low a sirup density. For fruits which are pungent or sharp in flavor, controlling sweetness by using a combination of ingredients is not so important. In the ice cream industry too, a combination of sugar and corn sweetener is sometimes used to reduce sweetness, in order not to mask delicate flavor, and to maintain as high a percentage of solids in the mix as when an all-sugar formula is used.

Hygroscopicity - Hygroscopicity is the ability of a substance to absorb and retain moisture. Some sweeteners are more hygroscopic than others, and this characteristic can be either an advantage or a disadvantage, depending on the product to be manufactured and the conditions under which it is produced and marketed. For instance, sugar and dextrose are commonly considered to be in the non-hygroscopic category, while corn sirup solids, honey and invert sugar are well known to be hygroscopic. Although there is no known published information which indicates that dextrose is more hygroscopic than sugar, many food processors have indicated their beliefs that this was the case, especially in the case of dextrose hydrate, possibly because it is known to contain from 8 to 9 percent of water of crystallization. Corn sirup definitely is hygroscopic, and in its dehydrated (solids) form, it absorbs moisture quickly when exposed to the atmosphere.

A hygroscopic sweetener has many advantages when it is desired that manufactured products hold moisture for prolonged periods of time. Examples of products of this nature are most types of confectionery, which must withstand a rather long shelf life, and icings, which are best when prevented from drying out and becoming brittle. On the other hand, the use of hygroscopic sweeteners is disadvantageous for products which require the absolute minimum of moisture, such chocolate. Manufacturers who desire to utilize hygroscopic sweeteners in certain products have been able to eliminate some of their handling and storage difficulties through air-conditioning of factories and proper packaging. Hard candies containing an excessive proportion of corn sirup tend to become sticky in hot humid weather. The use of some corn sirup, however, keeps hard candy from graining excessively. Thus, a balance of sweeteners in confections is necessary to achieve the desired sweetness, texture, structure, flavor and keeping quality.

In ice cream, where water is present in considerable quantity anyway, and a somewhat moist product is wanted, the hygroscopic tendencies of a sweetener are not objectionable and may even be desirable. "Corn sirup solids" are rather popular among the smaller ice cream manufacturers. However, the hygroscopic nature of corn sirup solids makes it desirable to use full-bag units, since exposure to the atmosphere for any length of time makes this product sticky and difficult to handle.

Crystallization and Solubility - Sweeteners also are used in food products to produce a desired degree of crystallization or, conversely, to prevent or control it. Sugar and dextrose are used to produce crystallization, while for many uses corn sirup serves to prevent or control it. Crystallization may also be controlled by means of invert sugar. The invert sugar may be added as such or may be produced from sucrose in the process of making certain products by adding small amounts of an inverting agent, such as tartaric acid or invertase. In many products, such as candies of the caramel, fudge and fondant types, it is desirable to prevent excessive crystallization.

Corn sirup is used in caramels in fairly large quantities to give chewy consistency. A smaller proportion of corn sirup or invert sugar is generally used in fondants and fudge to control crystallization and texture, yet maintain the desired degree of sweetness. Because more crystallization is necessary in hard candies, relatively more sugar and less corn sirup are generally used in this type of candy. It is also well known that results may be modified by varying the moisture content through control of temperature of the cook.

The tendency of a sweetener to crystallize varies inversely with its solubility. Because dextrose is not as soluble as sugar at ordinary temperature, dextrose tends to crystallize more in all dextrose sirups of the same density as all sugar sirups. A comparison of the relative solubility of sugar and dextrose is given in table 9. It will be noted that at temperatures above 60° C (140° F), dextrose is more soluble than sugar. This property, however, is considered to have little, if any, practical value. At lower temperatures, sugar is considerably more soluble.

The relative solubility of sweeteners at the lower temperatures is, of course, very important to a frozen food packer. When products are subject to quick freezing at low temperatures, it is essential that the sweetener dissolve readily and mix thoroughly throughout the pack, so that adequate results may be obtained from the use of the sweetener before all action is arrested by the freezing process. In freezing or canning fruit it is necessary for an exchange to be effected between the natural juice within fruits and the sweeteners used in the packing media, if the added sweeteners are to provide a uniform protection from spoilage and contribute as much as possible to the quality and flavor of the products.

Table 9. - Solubility of Sucrose and Dextrose in Water at Different Temperatures

Temperature	Dissolved by 100 grams of water	Dissolved by 100 grams of water
Degree centigrade	Sucrose (grams)	Dextrose (grams)
0.000	179.2	-
0.50	-	54.32
20.00	203.9	-
22.98	-	97.51
25.00	211.4	-
28.07	-	112.72
30.00	219.5	120.46
35.00	228.4	138.21
40.00	238.1	138.21
40.40	-	164.06
45.00	248.7	191.63
50.00	260.4	243.76
55.00	273.1	-
55.22	-	261.7
60.00	287.3	-
64.75	-	323.0
65.00	302.9	-
70.00	320.5	-
70.20	-	359.3
80.00	362.1	-
80.50	-	440.2
90.00	415.7	-
90.80	-	562.3

Source: U. S. Dept. of Commerce, National Bureau of Standards, Circular C440, Polarimetry Saccherimetry and the Sugars, U. S. Govt. Printing Office, Washington, D. C., May 1942; tables 134 and 137, pages 676 and 679.

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In preserving, where the products are cooked at high temperatures and later cooled or even refrigerated, the presence of dextrose in excess of given amounts has been found to cause crystallization. Problems resulting from the greater tendency of dextrose to crystallize at the lower temperatures are minimized when it is used in moderate proportions in conjunction with some other sweetener. For many products, however, this characteristic places a limitation on the percentage of total sweetener which may safely be comprised of dextrose.

Another important point relative to solubility and crystallization is that the total solubility of two sweeteners in a given amount of water is somewhat less than the sum of the solubilities of each of the sweeteners when separate solutions are made, using for each the same volume of water. This is because the solubility of a sweetener, when dissolved in an aqueous solution of another sweetener, is diminished as a result of the "salting out" effect of the second sugar. 11/

Another point is that in mixtures containing non-sugar solids, the solubility and crystallizing tendency of a sweetener may be significantly different from that prevailing in pure water solution. It is difficult, therefore, to figure exactly on the relative solubility and crystallizing properties of sugar and dextrose when they are to be used in products containing considerable non-sugar solids, such as ice cream, some confectionery, and frozen or preserved fruits.

In summary, corn sirup, invert sugar sirup, invert sugar and honey are popular as a portion of the total sweetener when it is essential to prevent or have a lesser degree of crystallization, while sugar or a combination of sugar and dextrose constitutes the bulk of the sweetener in products in which more complete crystallization is desired.

Density of Liquid Sweeteners and Moisture Content of Solid Sweeteners - Differences in the densities of liquid sweeteners, such as liquid sugar, corn sirup, molasses, and honey, and in the moisture contents of "dry" sweeteners-sugar, dextrose, and corn sirup solids-are often important characteristics affecting type and/or amounts of sweeteners used. The density of a liquid sweetening medium is commonly measured by use of a refractometer or a hydrometer and expressed in terms of refractometer solids, degrees Brix, or degrees Baumé. Degrees Brix is usually the approximate percentage of soluble solids. (Both sugars and non-sugar solids) to total weight of the material, and this is readily determined by use of a Brix hydrometer. In the case of pure sugar solutions, however, a sirup of 67° Brix is one with exactly 67 percent of the weight represented by solids (sugar) in solution, the remaining 33 percent being water. Degree Baumé is another measure of the density of a solution, and this is determined by use of a hydrometer bearing the name of its inventor, Antoine Baumé. A rough relationship between Brix and Baumé degrees for sirups of medium density is that Brix= Baumé x 1.87, if both Brix and Baume readings are corrected to the same temperature.

11/ U. S. Dept. Commerce, National Bureau of Standards, Cir. C. C440 Polarimetric Saccherimetry and the Sugars, May 1942, p. 361.

The density of liquid sugar varies considerably, depending on type and grade of product. The uninverted sucrose-type is most commonly sold at 66° to 67° Brix, while the inverted types are usually marketed at from 70° to 76° Brix. Corn sirup is sold according to its "commercial Baumé," 12/with the range from 42° to 44° covering most of the volume. In terms of total solids content, most corn sirups range from approximately 78 to 82 percent solids.

It is apparent, therefore, that the density of corn sirup is considerably higher than that of sucrose-type liquid sugar and somewhat higher than that of most inverted types.

For "dry" sweeteners, moisture content rather than density is the basis on which the proportions of solids and water are usually stated. Highly refined white granulated sugar usually has a moisture content of less than 0.10 of 1% and, for all practical purposes, can be said to be moisture-free. Incompletely refined sugar may have a somewhat higher moisture content. Dextrose is of two principal types: dextrose hydrate contains approximately 8 percent water (of crystallization), while anhydrous dextrose is as free of moisture as refined sugar. It is estimated that from 85 to 90 percent of the dextrose produced in 1949 was dextrose hydrate. 13/

It is necessary to make allowances for the variations in water content of sweeteners when using them in the production of a given food product. The lower moisture content of sugar is often an advantage, since the same solids content of a manufactured product can be obtained with a smaller amount of this sweetener. Dextrose hydrate is commonly considered about 65 or 70 percent as sweet as sugar. Since it consists of 92 percent solids and only 8 percent of water (of crystallization), dextrose may be used advantageously in place of sugar in instances where reduced sweetness and relatively little change in body, or density, is desired, as contrasted with results when using sugar. The same would be true for corn sirup solids, which has a sweetness of approximately 50 percent of that of sugar and a solids content of about 96.5 to 97.5 percent. In using sirups, however, more allowance must be made for the greater water content.

Molecular Weight, Osmotic Pressure, and Freezing Point Depression - The molecular weights of the sweeteners vary considerably and have a significant effect upon the lowering of the freezing point and upon osmotic pressure. Differences in molecular weights are an important consideration in making products such as ice cream, canned or preserved fruits, and in frozen foods.

12/ The Baumé of corn sirup is measured ordinarily to 140°F. and adjusted to 100°F. to obtain "commercial Baumé." Commercial quotations are for commercial Baumé densities, which are approximately 1° Baumé lower than Baumé to 60°F.

13/ Corn Industries Research Foundation's estimate.

Dahlberg and Penczek [14] found the molecular weights of sugar and corn sweeteners with given moisture contents to be as follows:

Sweetener	Moisture Content	Molecular weight (anhydrous basis)
Dextrose (hydrate)	9.54	180.11
Corn sirup (high enzymatic)	14.00	258.40
Sugar	0.25	342.17
Corn sirup solids	2.35	404.70

The freezing points of the solutions of these four sweeteners at various concentrations, expressed on a dry or solids basis, are given in figure 16. It will be seen that for any given concentration of these solutions the freezing point is correlated directly with the molecular weight; that is, the higher the molecular weight the higher the temperature at which the solution will freeze. The differences in degree to which these sweeteners depress the freezing point make it necessary to adjust the storage temperatures for ice cream in accordance with the type of sweetener used.

Variation in the molecular weight of sweeteners is related to number of dissolved molecules (particles) at a given concentration and, therefore, influences osmotic pressure. The lower the molecular weight of a sweetener, the larger the number of dissolved molecules in solutions of comparable concentration and the greater the osmotic pressure. Since the molecular weight of dextrose is much lower than that of sugar, there are more dissolved molecules (at given concentrations) and hence greater osmotic pressure. This greater osmotic pressure of dextrose in solution is important in preserving, where a quick interchange of the natural juice of the fruit and sweetener is desired.

Fermentation and Preservation - Sweeteners may be fermented for certain purposes or they may be used to preserve products from fermentation. These properties are important in the case of bread, jams, jellies, and preserves, but less important in canned and frozen foods. Naturally the use of sweeteners in all of these products is for various other purposes also, and the total effect of a sweetener must be considered in making a choice as to which one or ones to use.

In making bread, for instance, it is essential that sufficient sweeteners be provided for yeast food if proper leavening is to take place. The natural sugars supplied by the flour itself provide a part

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14/ Dahlberg, A. C. and Penczek, E. S., Dextrose and Corn Sirup for Frozen Desserts, N. Y. Agric. Exp. Sta. Bull. 696, Geneva, N. Y., October 1940, p. 10.

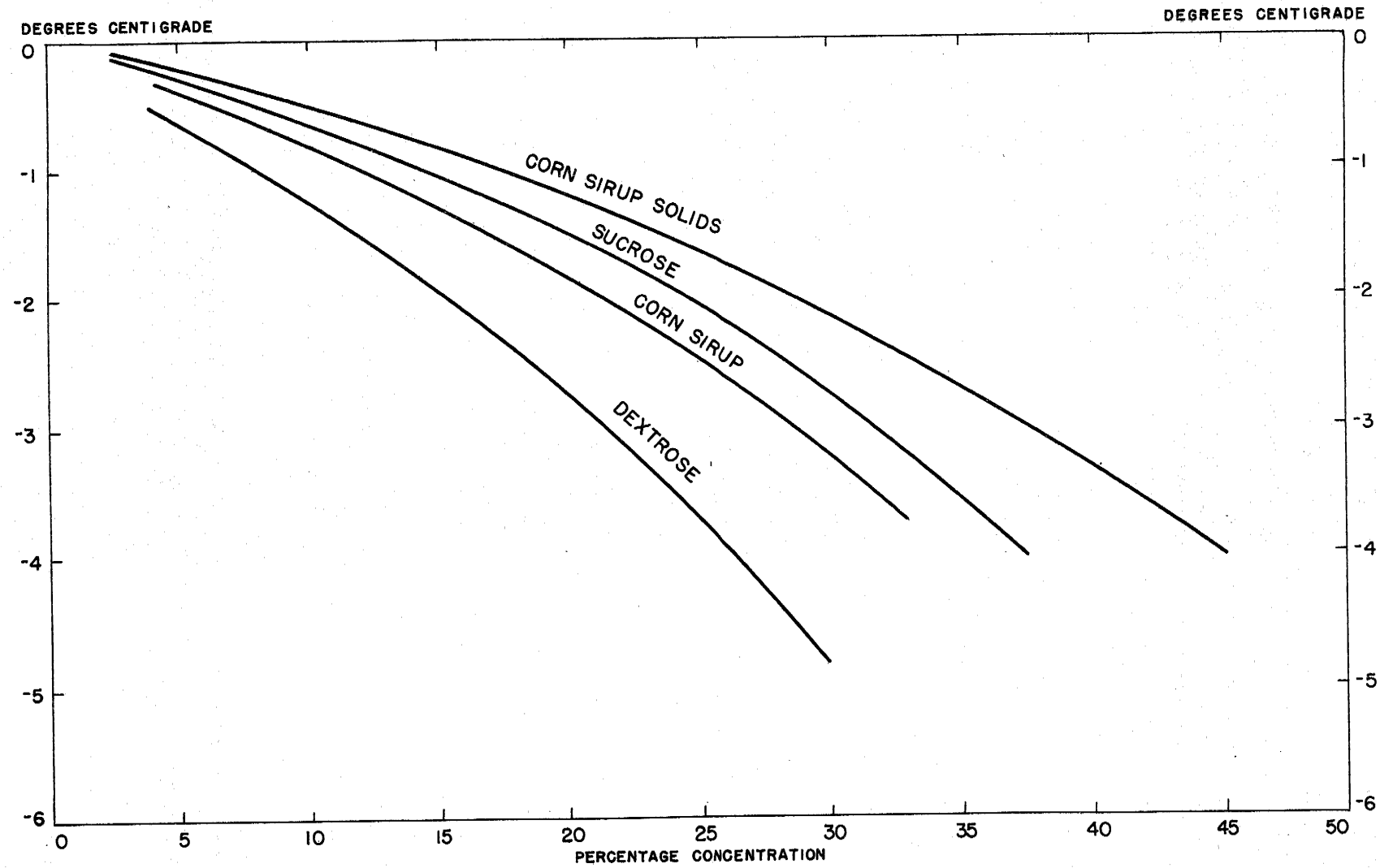

Figure 16.--The freezing points of sweetener solutions expressing concentration as the percentage of actual dry solids.

Source: Appendix. Table 61

of this sweetener, but the remainder comes from the addition of sugar, dextrose, or some other sweetening agent. Many bread bakers consider sugar and dextrose equally satisfactory insofar as producing the desired amount of fermentation is concerned. Both dextrose and sugar ferment rapidly with yeast, dextrose a little faster, it is claimed. The dextrose portion of corn sirup and corn sirup solids will also ferment rapidly, but because of their higher sugars and dextrin content, these products are considered less desirable than sugar or dextrose for use in fermenting the dough, giving desirable texture to the loaf and helping to color the crust.

In preservers' items, as the name implies, sweeteners are essential to "preserve" or protect the products from spoilage resulting from fermentation. Most bacteria and yeasts will not grow when the concentration of sweetener solids in preserves is above 65 percent. 15/

Therefore, if the sweetener content of preserves is raised to this figure or above, the product will be likely to keep indefinitely without spoiling or fermenting. Sweeteners also preserve for a longer period the natural colors of the fruit. All of the sweeteners are acceptable from the standpoint of building up sweetener solids to prevent yeast or bacterial growth in jams, jellies, and preserves. It is true, of course, that larger amounts of dextrose hydrate, corn sirup solids, or corn sirup, than of dry sugar would have to be used to supply sweetener solids, because of the smaller percentages of solids in the corn sweeteners. Since a dextrose solution has greater osmotic pressure than a sugar solution of equal density and the property of entering the pores of the fruit more rapidly, the dextrose would have greater preservative action. It has been claimed by some that use of a combination of sugar and corn sweetener in preserving and canning result in better preservation of fruit colors and natural fruit flavors, better texture and other desirable product characteristics. Adverse effects, however, have been reported when corn sweeteners were used, with sugar, in excess of certain proportions.

In frozen fruits, one purpose of sweeteners is to seal the product against contact with the air, thereby preventing oxidation during the interval required for the sweetener to penetrate the membranes of the fruit. It is necessary for the sweetener to mix thoroughly with and coat the surface of fruits before the freezing begins, if it is to constitute protection against oxidation and fermentation. Sweeteners also aid in preventing excessive shrinkage and in maintaining the natural flavor of most frozen fruits. There is some thought that a combination of sugar and corn sirup results in less oxidation, better preservation of color and flavor, and less shrinkage than when sugar alone is used.

15/ Meschter, E. E., **Jam and Jelly Making**, Food Industries, June 1949, p. 67.

However, use of corn sirup in greater than specified percentages seem to impart an objectionable dextrin-like flavor. 16/

In canned foods, the use of sweeteners is primarily for reasons other than protection against fermentation, since this protection may be obtained fairly well through pasteurization by heat and by packing in air-tight containers. However, it is not unusual for canners to take the extra precaution of using what is known as a "Canner's grade" of sugar, which has been treated by ultra-violet rays or produced by special care to reduce the count of thermophilic bacteria sometimes present in the sugar. The "Canner's grade" sugar is in demand by packers of non-acid types of vegetables, but apparently there are only a few canned food items in which spoilage due to this cause is a particular problem. Apparently the acidity in most items, especially the fruits, is high enough, together with the heat treatment, to prevent the growth of any thermophilic bacteria present. However, canners who use "Canner's grade" sugar in the non-acid vegetable items often use it in all of their products to avoid handling two types of sugar and to prevent errors in using the wrong sugar in some item.

In canning fruits, some of the sweetener enters the pores of the fruit and is exchanged for a part of the natural juices therein. Use of a sweetener also aids in preserving the color, flavor, and texture of canned fruits. The greater osmotic pressure of dextrose solutions is not as important in canning as in preserving. In canning it makes little difference whether the exchange of sweetener for the natural juices of the fruit is fast or relatively slow, whereas in preserving a rapid exchange is desirable. One of the primary purposes of the sweetener in preserving is control over fermentation, while in canning this control is achieved largely through other means.

Flavor - Presence or absence of flavor (other than sweetness) in a sweetener, or imparted to a food product during the processing because of some inherent quality in the sweetener, is also a major factor affecting choice of sweetener. Highly refined sugar and dextrose have no perceptible flavors other than sweetness. However, both these sweeteners tend to bring out the natural flavors of fruits and many other products. Grades of sugar which are not highly refined usually impart some flavor other than sweetness. While the authors do not know of any scientific literature relative to the subject, some food processors reported that they had found that dextrose tended to impart off flavors in certain processed food products. As a rule these reports were received from processors who had used dextrose in relatively large proportions. The dextrin content of corn sirup, especially the regular and low conversion types, was reported by several users to have the effect of masking delicate flavors of some products and, in some cases, to impart an undesirable flavor to the end product. Several other sweeteners, such as brown sugar, maple sugar and sirup, and sugarcane molasses are used primarily because they impart certain desirable

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16/ See below section on frozen fruit for more detailed discussion of this point.

flavors to a product. However, this attribute makes these sweeteners objectionable for other uses.

Price Relationships

One of the most important factors governing a food processor's choice of sweetening ingredients is the price differentials between the several sweeteners. Realization of the importance of price relationships requires a basic understanding of the price structure for sugar and the corn sweeteners, how delivered prices of each are determined, and the method used, if any, in gearing the price of one sweetener to another.

The Pricing of Refined Crystalline Cane Sugar - Refined sugar is priced on a basing-point system, the base points being the seaboard cane sugar refining points of Boston, New York, Philadelphia, Baltimore, Savannah, New Orleans, Sugar Land (Texas), and San Francisco. (See figure 17). The prices of refined cane sugar are not always the same at all of these base points but the differences are usually rather small. These prices are generally known as the "basis prices." Such approximate uniformity of prices is due to the highly homogeneous nature of the product and to the fact that for the Atlantic and Gulf refiners, the sources of supply of a large percentage of their raw sugar are identical; i.e., Cuba, Puerto Rico, and the Philippines. Because of this uniformity, and because of the concentration of refining activity in the New York City area, the seaboard refinery price of sugar sometimes is referred to as the New York price. All further references in this report to "basis price" or "New York price of refined sugar" should be construed as being the quoted price at seaboard refinery base points. The usual quoted price is in terms of 100 pound paper bags of standard granulated sugar, with differentials being applicable to specialty grades and smaller size packages.

The effective selling price of sugar is 2 percent less than the quoted price, because of the discount allowed for cash settlement within 10 days. The price of cane sugar at any city other than the refinery base points includes the basis price plus the freight charge to that city. In addition there is a 3 percent transportation tax, a one percent tax, and a 2 percent "compensation" charge. 17/ The freight cost plus these three charges is known as the "prepay." A typical formula for determining the prepay for a standard carload of sugar is arrived at as follows:

	100%	published freight rate
plus	1%	tare (sometimes 1½%)
plus	3.03%	transportation tax (3% x 101)
	104.03	

100% - 2% (for net cash within 10 days) = .98

$$\frac{104.03}{.98} = 106.153$$

106.153 x freight rate = prepay

17/ The 2 percent discount for prompt cash payment is also applied to the prepay portion of the delivered price, thus the aforementioned 2 percent charge is made to compensate for this portion of the discount.

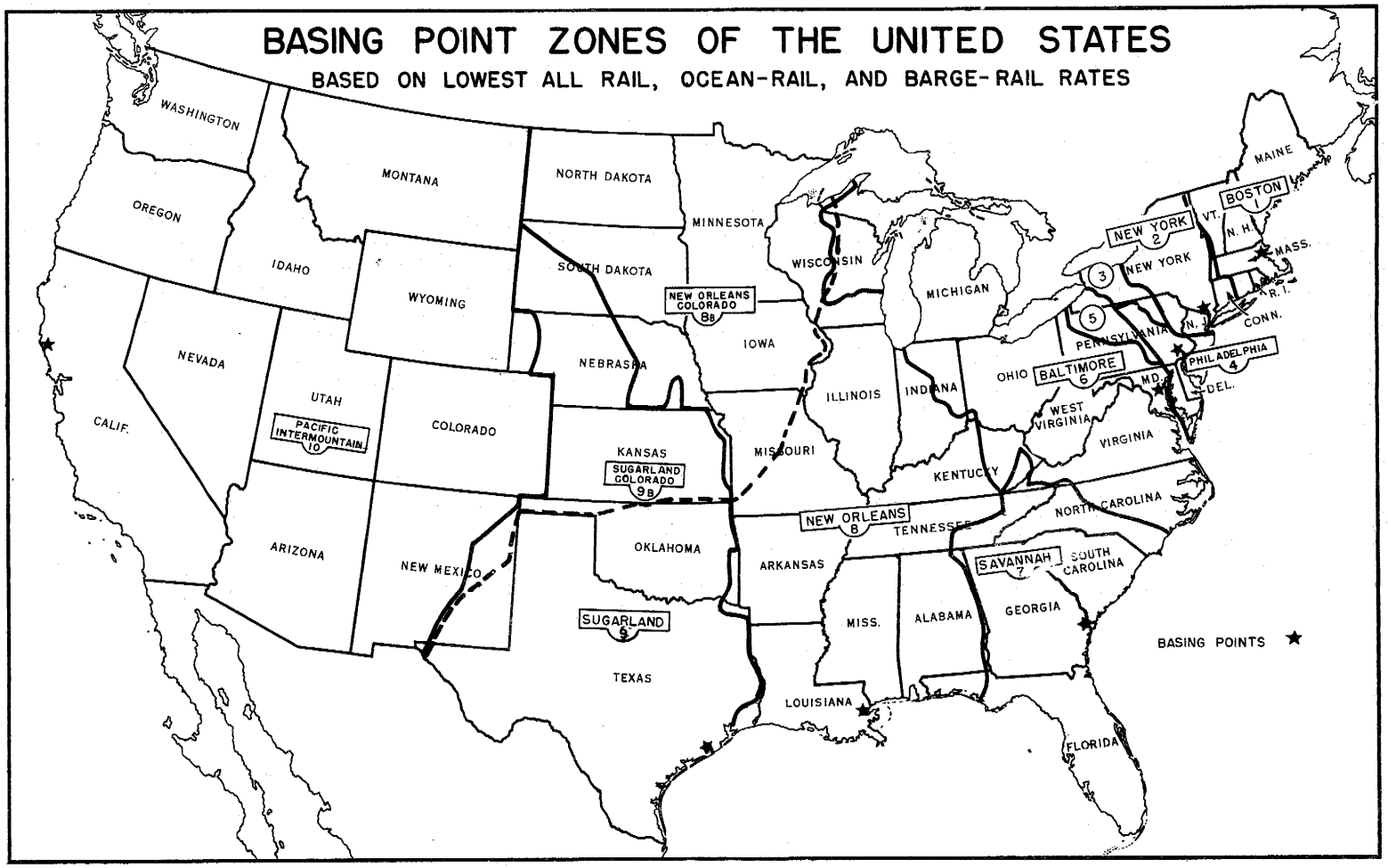

Figure 17.- The map describes the basing zones as computed from rates in effect as of about May 6,1948. Some over-all percentage increases have been granted since that time but in effect the general picture remains essentially the same. In the map, zone 3 is served equally freightwise by New York and Philadelphia. Likewise, zone 5 is served equally by Philadelphia and Baltimore. The broken line cutting zones 8 and 9 represents the points where freight costs from the Colorado beet district are just about equal to the prevailing seaboard cane refinery prepays. Zone 10 describes the territory based freightwise on San Francisco. Actual selling and distributing territories of the refiners, of course, often are quite different from the basing point zones.

Source: American Sugar Refining Company.

The location of the cane sugar refineries, beet sugar processors, the eight seaboard base points, and the approximate territories of lowest freight for each of the base point cities are given in figure 1.

Much of the cane sugar sold by an individual refiner is sold within the areas where the freight rate from the refinery basing point to the buyer's location is less than the freight rate from any other basing point. In some territories more sugar is produced than can be sold in that area by refineries located there. These refiners, therefore, must sell sugar in areas closer freightwise to other refiners. The prepay charges on such sales are determined not from the freight rate from the seller's refinery location to the buyer's location but from the freight rate to the buyer's location from the basing point nearest to the buyer freightwise. The seller absorbs the excess of actual freight charges above those which would have prevailed if the sugar had been shipped from the refinery nearest freightwise to the buyer.

The Pricing of Refined Crystalline Beet Sugar - None of the beet sugar factory locations is a base point, but those in northern California are, of course, fairly close freightwise to San Francisco. Historically, beet sugar is quoted at a slight differential under refined cane sugar. The quoted differential varies somewhat, but ordinarily is from 10 to 20 cents per 100 pounds. The price of beet sugar at any interior point is the basis price of cane sugar less the differential, plus the "prepay." The prepay is calculated on the basis of freight from the nearest seaboard cane sugar refinery to that point. Any prepay charges in excess of those which would have prevailed on cane sugar shipped from the nearest freightwise refinery are absorbed by the beet processor. Likewise, if the actual prepay charges incurred in moving beet sugar from a factory to a buyer's location are less than those from the nearest freightwise seaboard cane refinery to that point, the beet processor has a "freight pick-up." Thus, a beet processor located in Utah or Colorado who sells sugar in St. Louis or Chicago must absorb freight because the freight is less from New Orleans to those two cities than from any beet factory in Colorado or Utah. Conversely, on sugar sold in Denver or Salt Lake City by these beet processors there would be a freight pick-up to the extent that the freight from the factory to these cities was less than the freight from San Francisco, the nearest freightwise basing point to Denver and Salt Lake City.

The Pricing of Liquid Sugar - Liquid sugar is priced on the basis of the total sugar solids which it contains. Since most of the soluble solids in liquid sugar are composed of sucrose or sucrose and invert, it commonly is sold on the basis of degrees Brix (a measure of the percent of total weight composed of soluble solids). All liquid sugar of the sucrose sirup type and most of that of the partially inverted type sells at a differential, on a solids basis, under the price of granulated sugar. In general the differential is 15 cents per 100 pounds, on a solids basis, under dry sugar.

It is customary to deliver liquid sugar in tank trucks in those metropolitan areas adjacent to the point of production. For deliveries of this type, it is customary to sell on a delivered, prepaid basis, with delivery charge based on the solids content. In this way the delivery charge for 150 pounds of liquid sugar containing 67 percent sugar solids is approximately equal to that for 100 pounds of dry sugar. For shipments to destinations sufficiently removed from the point of production to warrant shipments by rail tank cars, liquid sugar usually is quoted f.o.b. refinery on a sugar solids basis. However, railroads assess freight charges on the basis of the total weight of the sirup, and in some areas, the rate per 100 pounds of sirup is the same as for 100 pounds dry sugar. Thus, the delivered price to a liquid sugar user is the f.o.b. refinery price of the sugar solids plus freight on the entire weight of the sirup. To remain competitive with dry sugar, the sellers of liquid sugar often follow the practice of absorbing some of the freight charges on tank car shipments.

For liquid sugar of the sucrose sirup type, the weight of the water is about one-third that of the entire sirup. Therefore, the freight cost per 100 pounds on a dry-weight basis on liquid sugar of this type is about 50 percent higher than for dry sugar. As the degree of inversion is increased, the ratio of solids to total weight of the sirup is increased, and, of course, the cost of freight paid for water becomes less. Obviously, the higher the freight cost becomes on the same quantity of sugar solids, the sooner the discount at which liquid sugar sells is dissipated. For example, for liquid sugar of the sucrose sirup type, the savings by the differential are just offset by the added freight cost when the freight from refinery to destination on the weight of 100 pounds of dry sugar is exactly double the differential. With a 15-cent differential, therefore, liquid sugar becomes more expensive on a solids basis when the freight rate on the dry sugar is more than 30 cents per 100 pounds.

To take a simplified arithmetical example, assume dry sugar sells at $8.00 per 100 pounds and a freight charge to destination is 30 cents, making the delivered price $8.30. 18/ With a sucrose sirup liquid sugar of 67 percent solids at 15 cents under dry sugar, the quoted price, f.o.b. refinery would be $7.85. In order to get 100 pounds of sugar solids in this type of liquid sugar, 150 pounds of sirup are required. Assuming equal freight rates on sirup and dry sugar, the freight is 1½ times as much, or 45 cents. Adding $7.85 and $0.45, a delivered price of $8.30 per 100 pounds sugar solids is obtained or the same price as the dry sugar in this example. If, of course, the differential of liquid sugar under dry sugar is increased to 20 cents, the area in which liquid sugar is equal to or lower in price than dry sugar is expanded to the zone in which the freight per 100 pounds of dry sugar is 40 cents or less- in other words to the zone where the freight rate is not more than twice the differential in quoted prices of dry and liquid sugar.

18/ The 2 percent discount for net cash 10 days, possible freight absorption, and other complicating factors are ignored in this example.

The point at which it becomes uneconomical for a manufacturer to use liquid sugar may not coincide with the point at which the delivered price of sugar solids in the liquid sugar exactly equals the delivered price of dry sugar. Economies of storage and in-plant handling may be sufficient to warrant a user paying a somewhat higher price for liquid sugar on a solids basis. And, as stated above, the producers of liquid sugar often absorb some of the freight charges.

The Pricing of Dextrose - The price of dextrose generally is geared directly to the price of dry sugar, see figure 18, and the prevailing prices at all points are arrived at in approximately the same manner as for dry sugar. The delivered price of dextrose at any point is the delivered price of sugar at that point less a certain differential which is usually constant for all points. 19/ Since seaboard cane sugar refineries are base points in sugar pricing, the dextrose price at any interior point is this base price of sugar less the differential, plus the prepay on sugar from the nearest freightwise seaboard cane sugar refinery. However, in areas where beet sugar is sold, the differential applies to the price of beet sugar. The differential varies from time to time, but as a rule is maintained at about 18 or 19 percent, or 85 cents to $1.00 under sugar. The highest New York differential since 1935 was $1.60 in July 1948 and in February and March of 1949. During the months July through September of 1946, dextrose prices were higher than those of refined sugar.

Dextrose is produced at the interior points of Argo and Pekin, Illinois; Roby, Indiana; Clinton, Iowa; Kansas City, Missouri; and sometimes at Cedar Rapids, Iowa. Argo and Roby are within the Chicago switching area and for all practical purposes, are herein considered to be synonymous with that city. 20/ Since New York and San Francisco are both sugar basing points, the price of dextrose at these cities is simply the New York cane sugar price less the differential, the freight from mid-western wet corn milling plants being absorbed by the seller. In Chicago or St. Louis, the price of dextrose is equal to the delivered price of beet sugar at these points less the differential.

The Pricing of Corn Sirup - The delivered price of bulk corn sirup is arrived at by adding the full freight rate to an f.o.b. mill price but meeting the price of competitors where such price is arrived at in the same manner. In effect, this is an f.o.b. mill price plus freight from the mill nearest freightwise to the destination point. As illustrated in figures 19 and 20, the price of corn sirup is tied to the price of corn and not to the price of sugar as in the case of dextrose. However, the price of sugar serves to place an upper limit on corn sirup prices. In other words, corn sirup prices fluctuate with the price of corn except that the price of sugar sets a ceiling on the upward movement of these fluctuations.

19/ Sometimes a special differential is in effect in a particular city in order to meet a specific competitive situation. Also a uniform delivered price of dextrose often prevails over a fairly large area, such as the West Coast.

20/ There is a switching charge made for movement of dextrose from those plants to a Chicago user.

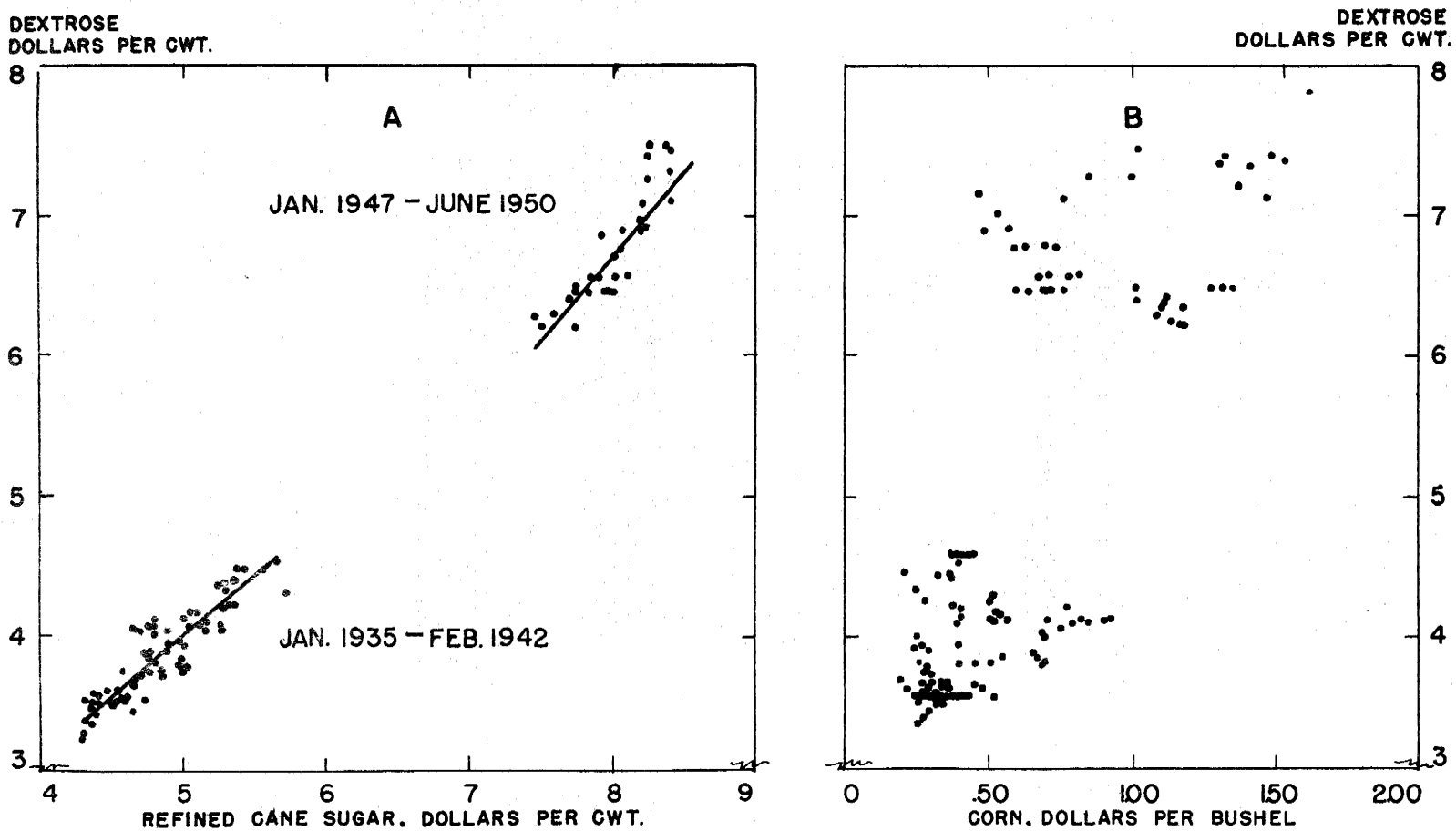

Figure 18.--Average wholesale price of refined cane sugar, New York, net corn cost per bushel to wet millers, Chicago, and average wholesale price of dextrose hydrate, New York, Jan. 1935-Feb. 1942 and Jan. 1947-June 1950.

A. Jan. 1935-Feb. 1942 - The line of average relationship shows a rise of $0.81 in the price of dextrose for every rise of $1.00 in the price of sugar. Jan. 1947-June 1950 - A rise of $1.19 in the price of dextrose for every rise of $1.00 in the price of sugar.

B. The scatter diagram for dextrose prices and the net cost of corn to the wet miller shows very little relationship between the two.

Source: Appendix. Tables 62, 63, 65

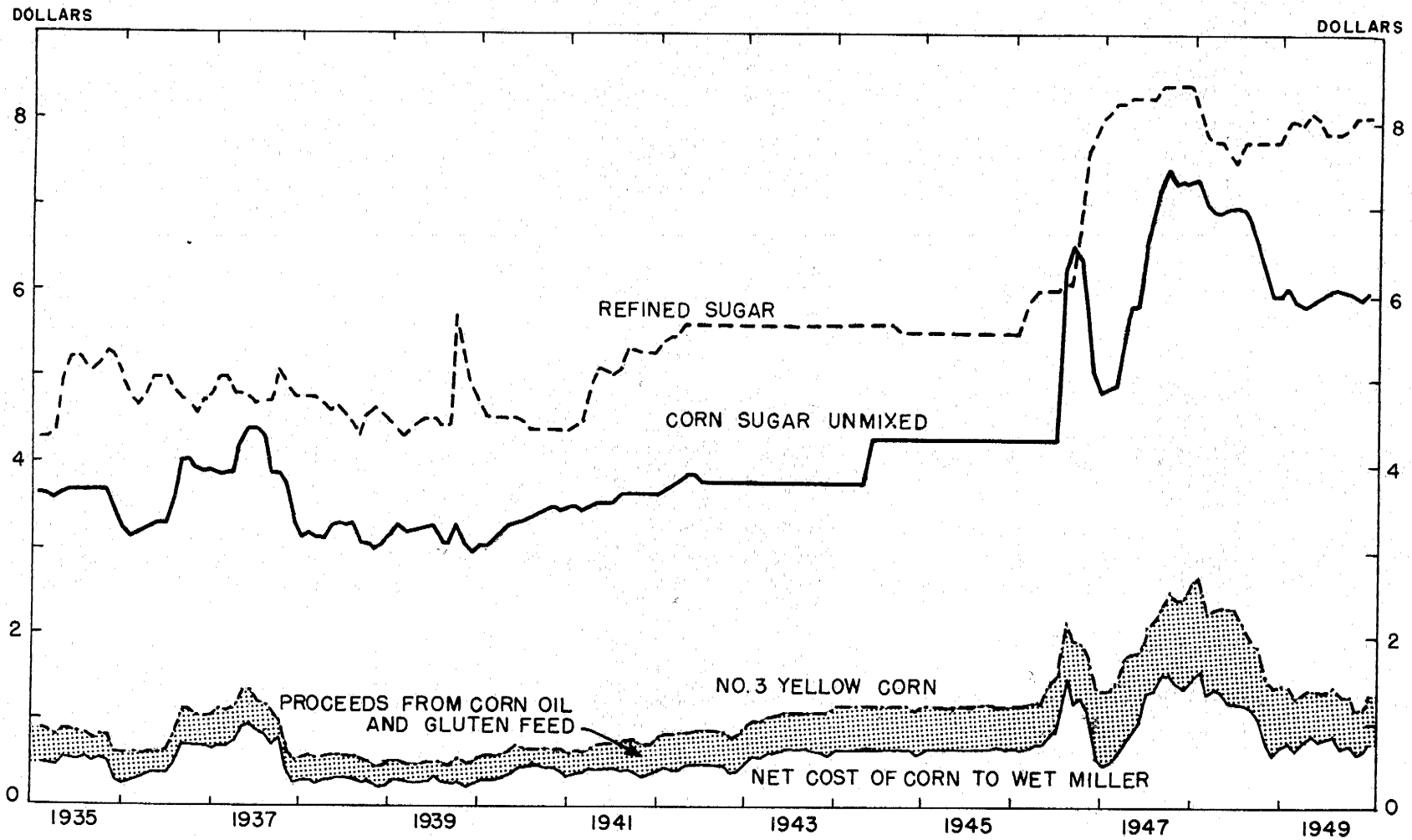

Figure 19. - Prices of refined sugar, average gross wholesale, per cwt., New York; corn sirup unmixed, 43° Be, average wholesale, gross, per cwt., New York; No. 3 yellow corn, average weighted price per bu., Chicago; and net corn cost per bu. to wet millers, Chicago, 1935-49.
Source: Appendix. Tables 62, 64, 65, and 66.

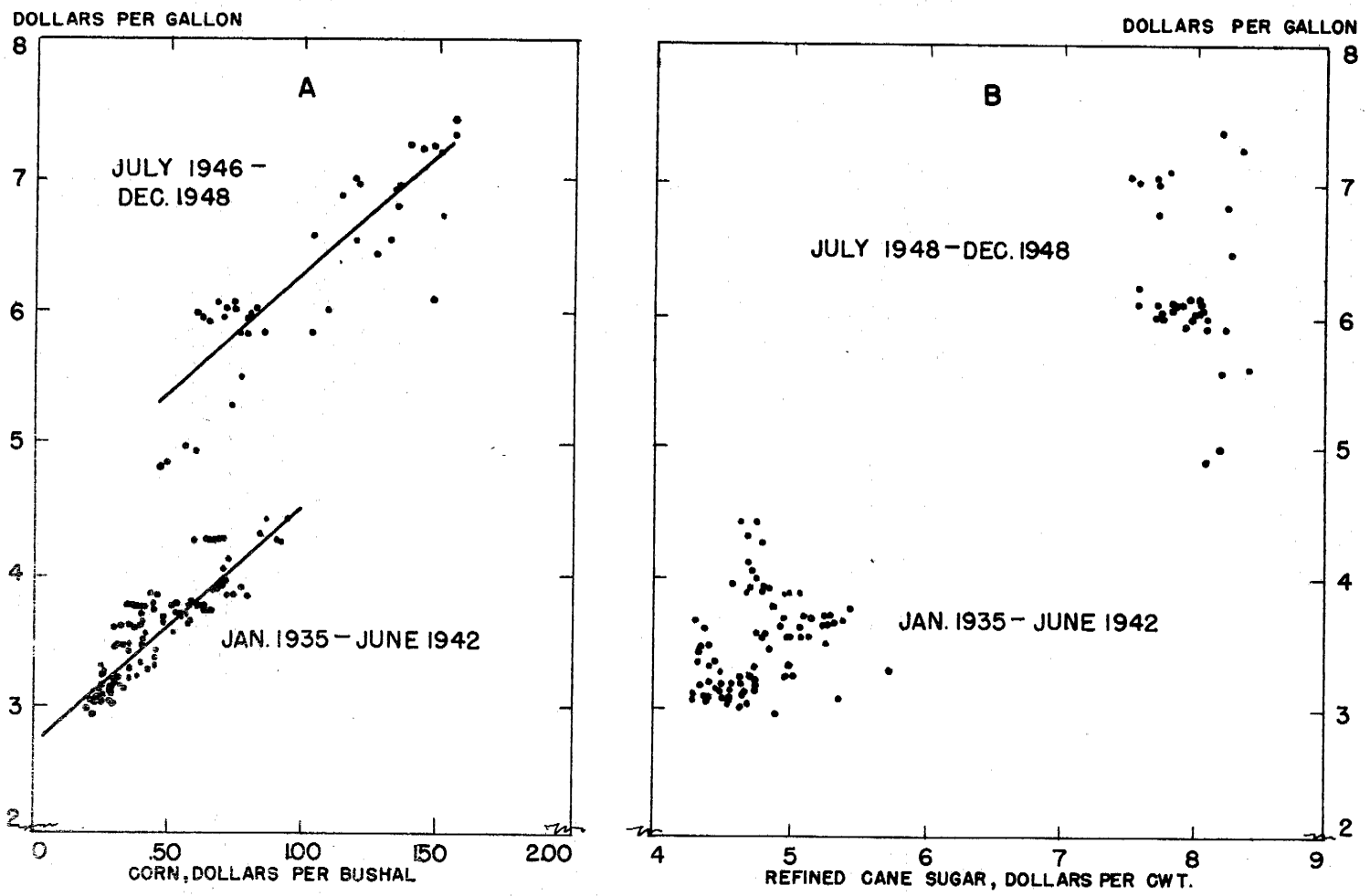

Figure 20.--Net corn cost per bushel to wet millers, Chicago, average wholesale price of refined cane sugar, New York, and average wholesale price of corn sirup, 43° Be, New York, Jan. 1935-June 1942 and July 1946-Dec. 1949.

A. The line of average relationship for each period--prewar and postwar--shows a rise of $1.81 in the price of corn sirup for every rise of $1 in the net cost of corn to the wet miller

B. The scatter diagram for corn sirup and sugar shows very little relationship between the prices of the two sweeteners.

Source: Appendix. Tables 62, 64, 65

Another factor which wet millers consider when pricing corn sirup is by-product credits. The important item from the wet miller's standpoint in pricing corn sirup is not simply the price he pays for corn but the net cost of the corn to him after subtracting from the cost of corn the proceeds from by-products, principally feeds and oils (See figure 18). Thus, a decrease in the price of corn may not result in a lower price for corn sirup if the proceeds from by-product feeds and oils also have declined. Since such feeds and oils are sold in competition with other feeds and oils in general, and since dextrose prices are geared directly to sugar, corn sirup and starch prices remain the primary ones which may be adjusted to compensate for changes in the cost of corn. However, as stated previously, sugar prices and not the net cost of corn set a limit on the upward movement of corn sirup prices.

Prices usually are quoted for 42 or 43° Baumé regular conversion corn sirups with differentials applying to sirups of higher and lower Baumé. High conversion sirups sell at a premium over all regular and low-conversion types while low conversion sirups sell at a premium over the 42, 43 and 44° Baumé regular corn sirup. The price differentials for corn sirups over 42° Baumé sirup prices are generally constant and approximate the following:

Type of Corn Sirup	Price (Base price plus)
42° Bé Regular	-
43° Bé Regular	5¢
44° Bé Regular	12¢
Low conversion	15¢
45° Bé Regular	19¢
High conversion	35¢

The price differential between the highest priced corn sirup and the price of 42° Bé sirup was less than 8 percent of the base price in 1948. For a relatively small additional sum, the manufacturer could select the type of sirup which best suited his needs. On the other hand, it may be seen in Figure 21 that the container differential and freight charges may be more important factors in a manufacturer's decision concerning sweetener usage. In 1948, the difference between tank car prices and the price of barreled sirup, carlots, averaged more than 23 percent of the base price, tank cars, while freight and other charges between Chicago and New York averaged between 16 and 19 percent of the Chicago base price. Clearly then, the Chicago purchaser of corn sirup in tank car lots is in a better position as a sweetener user than the Chicago purchaser of corn sirup in other containers or the New York purchaser of corn sirup in any container. Thus, the nearness of a manufacturer to the source of supply and his ability to handle bulk quantities may determine, in part, his usage of corn sirup as a supplement to sugar usage.

The Pricing of Corn Sirup Solids - Corn sirup solids prices are tied to corn sirup prices. It takes approximately 3.2 bushels of corn to produce 100 pounds of corn sirup solids, and only 2.5 bushels for 100 pounds of corn sirup. Also, the production process for making corn sirup solids is

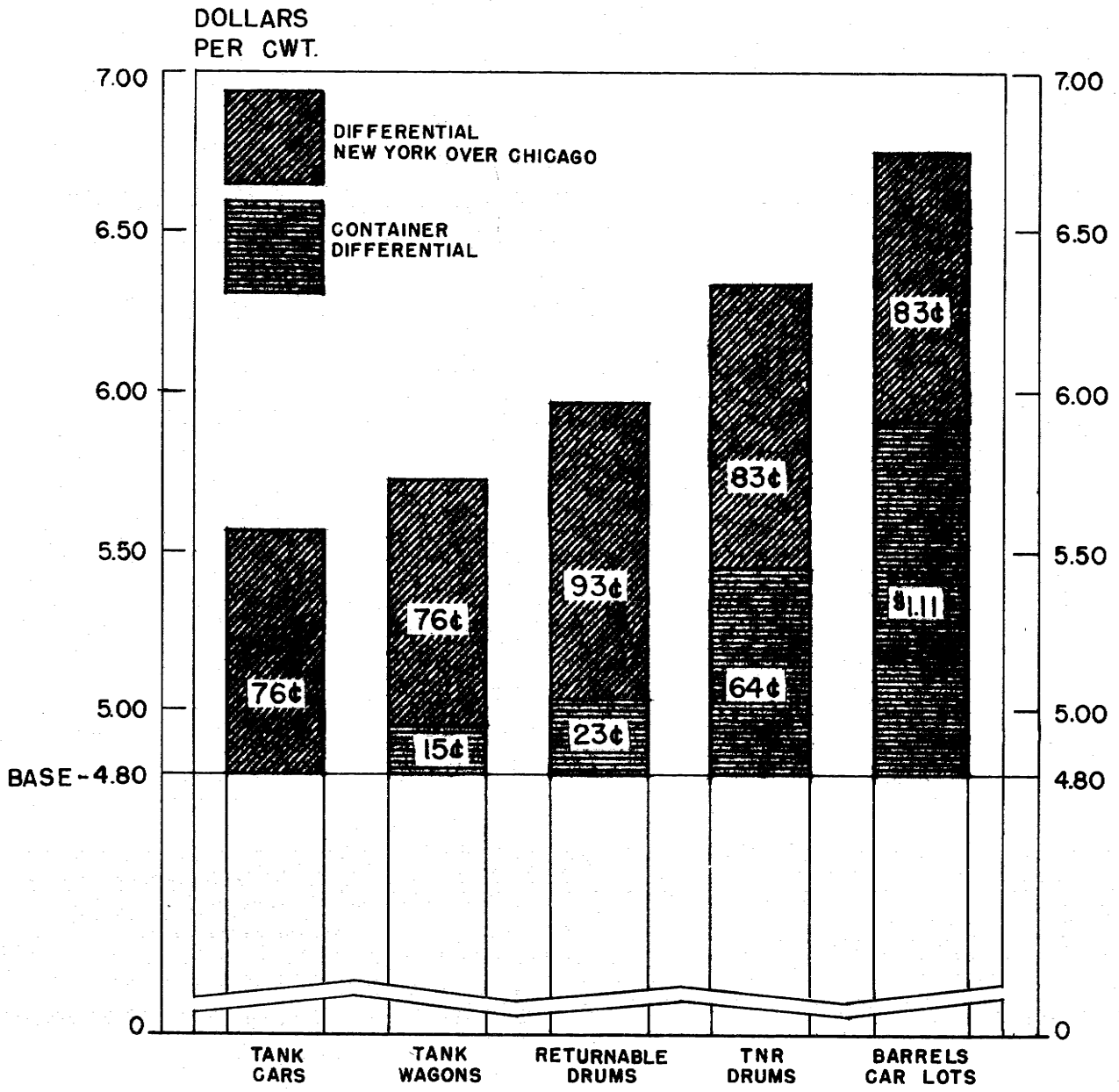

Figure 21.--Average gross price of corn sirup, unmixed, 42° Bé., by type of container, Chicago and New York, 1948

Source: Reports of Corn Products Refining Co. to U.S.D.A.

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more expensive than that for corn sirup. In pricing corn sirup solids, the general practice is to establish a mill price sufficiently above the mill price for corn sirup to cover the added cost of ingredients and processing, including a return on the investment for the required processing facilities. However, the price of sugar again dictates the upper limit on the mill price of corn sirup solids. To remain competitive, solids must sell at a discount under sugar.

Once a mill price for corn sirup solids has been established, the prevailing price at any point is the mill price plus freight to that destination. Since corn sirup solids are produced in the mid-west (plants at Roby, Indiana; Clinton, Iowa and Keokuk, Iowa), the method of arriving at delivered prices results in higher prices for seaboard consuming centers like New York, Philadelphia, and San Francisco, than for interior points like Chicago or St. Louis. On the other hand, sugar prices are lowest at seaboard sugar refining points, and in general, increase directly with the distance from the nearest refinery. Therefore, rigid adherence to the above method of arriving at corn sirup solids prices would result in a significantly greater differential between sugar and corn sirup solids prices in Chicago than in New York. Since corn sirup solids must remain competitive with sugar, it often is necessary for the manufacturers of solids to sell in seaboard cities at a lower price than would result from application of the mill price plus freight. The lowering of corn sirup solids prices in seaboard and adjacent areas to meet sugar competition usually is achieved by the manufacturers' absorbing freight rather than by lowering the mill price. While the net result to the seaboard user might be the same in either case, the manufacturer wants to maintain the mill price relationship between solids and corn sirup.

Summing up, it may be said that (1) corn sirup solids are priced f.o.b. mill at a price sufficiently above corn sirup to cover the costs of added materials and processing, and (2) that the delivered price is kept sufficiently below sugar to meet the competition of that product, often requiring the absorption of freight as seaboard sugar refinery points are approached. Little direct attention is given to the relationship between solids prices and dextrose prices and solids often are priced above dextrose at seaboard points and below dextrose at interior points.

The Relative Cost of Using Sugar and Corn Sweeteners

Sugar and Dextrose - The quoted price of sugar, during the pre-war period of 1935-39, averaged 99.2 cents per 100 pounds more than the quoted price of dextrose hydrate (New York). The price differential between the two sweeteners after the discontinuance of sugar rationing averaged between $1.38 in 1948 and $1.44 per 100 pounds in 1949. To the extent that sugar can be replaced pound for pound with dextrose, such price differentials permit savings to be realized by the sweetener-using manufacturer. However, in interviews with manufacturers of all types of food products, a large number of dextrose users indicated that it

was necessary to adjust formulas for the moisture content of dextrose. As shown in Table 10, when an adjustment for moisture is made on the basis that dextrose hydrate contains 8 percent moisture, the cost of purchasing the dextrose is increased to 109 percent of the quoted price and the price differential between sugar and dextrose is considerably reduced.

Anhydrous dextrose, with a solids content approximating that of refined sugar, is often substituted pound for pound for sugar; however, the anhydrous variety of dextrose averaged $1.05 per hundredweight more than the quoted price of dextrose hydrate in 1948, resulting in a price which was higher than the cost of dextrose hydrate after adjustment for moisture content.

Many manufacturers interviewed in 1948 and 1949 indicated that adjustments were made for the lesser sweetening power of dextrose where it replaced a portion of the sugar content of a food product. However, if adjustment had been made for the moisture content of dextrose hydrate, the savings from replacement of sugar with dextrose was such that actual percentage adjustment for sweetness could not have exceeded 6 percent in 1947 and 12 percent in 1948 and 1949. In other words, if dextrose were substituted at a rate of more than 106 pounds (dry basis) in 1947 and 112 pounds (dry basis) in 1948 and 1949 21/ for 100 pounds of sugar to compensate for the lesser sweetness of dextrose, then any price advantage of dextrose over sugar would have been eliminated. Furthermore, it has been estimated that dextrose hydrate is between 65 to 70 percent as sweet as sugar. If adjustment is made on this basis then dextrose would cost the manufacturer considerably more than sugar. The values attributed to dextrose solids are primarily the added body imparted to the product, and the reduction of excessive sweetness when desired.

In conclusion, if a manufacturer replaces dextrose for sugar, pound for pound, then effective savings in sweetener costs per se are realized; if a manufacturer adjusts for the moisture content of dextrose (hydrate), then savings are only three-fifths those of the first instance (1949); and, third, if adjustments are made to compensate fully for the lesser sweetening power of dextrose a manufacturer makes no effective savings in sweetener costs.

Sugar and Corn Sirup - The price differential between sugar and corn sirup was greater in 1949 than in the pre-war period; i.e. corn sirup was relatively cheaper compared with sugar in 1949 than it was prior to World War II. However, the price of corn sirup was 72 percent that of sugar during the pre-war period. During 1949 corn sirup prices were 75 percent of sugar prices. The New York differential between the quoted prices for refined sugar and the quoted prices for 43° Baumé regular corn sirup, in barrels, averaged $2.00 per 100 pounds in 1949 as compared with $1.31 for the years 1935-39 (See Table 11).

21/ Obtained by dividing the price differential between sugar and dextrose (solids basis) by the cost of dextrose hydrate (solids basis).

Table 10. - Refined Sugar and Dextrose Hydrate: Prices and price differentials per unit of solids content, 1935-49

Year	Refined Sugar 1/	Dextrose Hydrate 2/		Differential	
		Quoted Price	Solids Price	Quoted Price	Solids Price
	(dollars per cwt.)	(dollars per cwt.)		(dollars per cwt.)	
1935	4.95	3.90	4.24	1.05	.71
1936	4.79	3.70	4.02	1.09	.77
1937	4.82	3.99	4.34	.83	.48
1938	4.57	3.58	3.89	.99	.68
1939	4.66	3.66	3.98	1.00	.68
1940	4.42	3.51	3.82	.91	.60
1941	5.02	4.10	4.46	.92	.56
1942	5.56	4.50	4.89	1.06	.67
1943	5.60	4.50	4.89	1.10	.71
1944	5.57	4.50	4.89	1.07	.68
1945	5.50	4.50	4.89	1.00	.61
1946	6.47	5.89	6.40	.58	.07
1947	8.29	7.18	7.80	1.11	.49
1948	7.76	6.38	6.93	1.38	.83
1949	7.97	6.53	7.10	1.44	.87

1/ Refined Sugar - Gross price including tax, New York

2/ Dextrose Hydrate - Quoted Price: Gross price, New York
Solids price: Assumes 92 percent solids, 8 percent moisture

Table 11. - Refined Sugar and Regular Corn Sirup, 43° Bé: Prices and price differentials per unit of solids content, 1935-49

Year	Refined Sugar 1/	C.S.U. 43° 2/		Differential	
		Quoted Price	Solids Price	Quoted Price	Solids Price
	(dollars per cwt.)	(dollars per cwt.)		(dollars per cwt.)	
1935	4.95	3.61	4.50	1.34	.45
1936	4.79	3.55	4.42	1.24	.37
1937	4.82	3.90	4.86	.92	-.04
1938	4.57	3.11	3.87	1.46	.70
1939	4.66	3.08	3.84	1.58	.82
1940	4.42	3.30	4.11	1.12	.31
1941	5.02	3.54	4.41	1.48	.61
1942	5.56	3.75	4.67	1.81	.89
1943	5.60	3.73	4.65	1.87	.95
1944	5.57	4.05	5.04	1.52	.53
1945	5.50	4.27	5.32	1.23	.18
1946	6.47	5.04	6.28	1.43	.19
1947	8.29	6.40	7.97	1.89	.32
1948	7.76	6.75	8.41	1.01	-.65
1949	7.97	5.97	7.43	2.00	.54

1/ Refined Sugar: Gross price, including tax, New York

2/ C.S.U. 43°; Gross price, New York. Solids content 80.3%.

The cost of 100 pounds of 43° Bé sirup, dry basis, equals approximately 125 percent of the quoted price of 100 pounds of sirup. Thus, the dry basis differential between sugar and corn sirup in 1949 was little more than one-fourth that of the quoted price differential. For instance, the average price of sugar in 1949 was $7.97 while the average quoted price of corn sirup (regular 43° Baumé) was $5.97 -- a differential of $2.00 per 100 pounds. When the quoted price of corn sirup was adjusted to a dry basis (assuming 80.3 percent solids) the average price for 1949 became $7.43 per 100 pounds, reducing the differential to only 54 cents. Where a manufacturer wished to adjust for the lesser sweetening power of corn sirup relative to sugar, this could be done only to the extent of 7 percent after an adjustment for moisture had been made. Any adjustment of more than 7 percent would eliminate the differential between the price of sugar and the cost of corn sirup on a solids basis. 22/

The above discussion has dealt with the relative cost of using sugar and 43° Baumé regular corn sirup, in barrels at New York. The cost of corn sirup to a New York manufacturer may be more or less than the above depending on the following factors: (1) The density of Baumé of the sirup, (2) the dextrose equivalent (D.E.) of the corn sirup which is used and (3) the container in which the corn sirup is shipped. Figure 18 presents the average 1949 New York price differentials between sugar and corn sirups of various Baume, D.E., and by type of shipping container. When the quoted price of corn sirup is used in determining the price differential, each of the three factors above contributes to the cost of corn sirup relative to sugar. In 1949, the New York price differential varied between $1.70 per 100 pounds for high conversion corn sirup in barrels and $3.16 for regular corn sirup, 42° Baumé, in tank cars.

If a manufacturer considers the cost of the solids content only of corn sirup in calculating the difference in price between sugar and corn sirup, the Baumé of the corn sirup loses most of its importance as a cost factor. Then, on a solids basis, the dextrose equivalent of a corn sirup and the type of shipping container determines the extent of the price differential between sugar and corn sirup. The cost of the dry substance, for instance, in 42° Bé regular corn sirup is higher than that for the other regular corn sirups and is only less than that of high conversion corn sirup. (See **figure 22**). In 1949, the New York price differential between refined sugar and corn sirup (dry basis) varied between 24 cents per 100 pounds for high conversion corn sirup, in barrels, and $1.98 for regular corn sirup, 44° Be, in tank cars. As shown in figure 22, when the cost of corn sirup is calculated on a dry basis the container differential becomes of relatively greater importance than for corn sirup on a quoted price basis. In 1949, the differential between the quoted prices for tank car lots and barrels, carlots, equaled $1.11 per 100 pounds, while the differential between the dry basis cost of tank car lots and barrels, carlots, varied from $1.32 to $1.42.

22/ Obtained by dividing the price differential between sugar and corn sirup (solids basis) by the cost of corn sirup (solids basis).

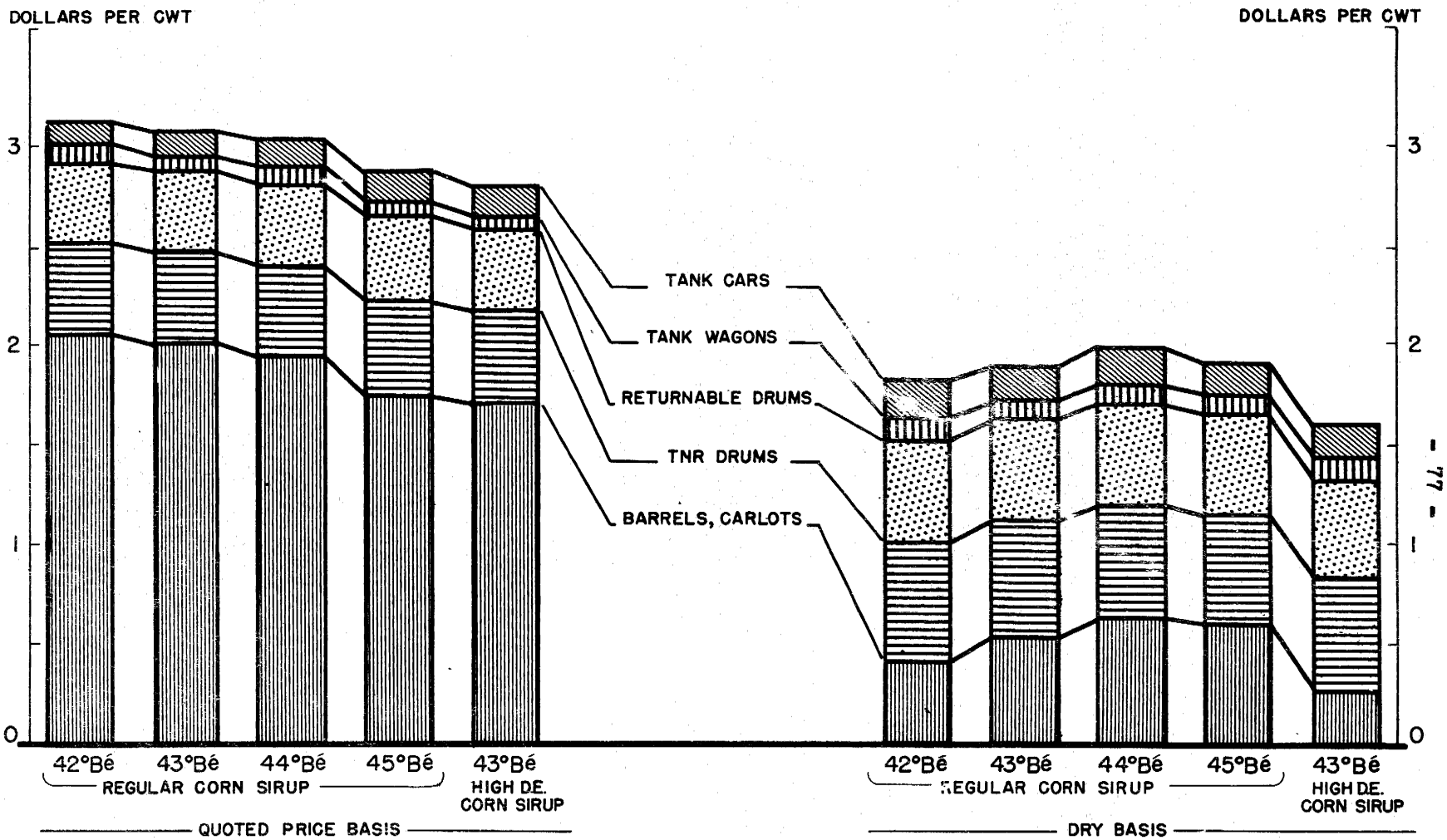

Figure 22.--Price differentials, according to quoted prices and prices on dry basis, between refined sugar and corn sirup unmixed, regular and high conversion, by type of container, New York, 1949.

Source: Reports of Corn Products Refining Co. to U.S.D.A.

Price data available indicate that during normal supply periods, corn sirup is purchased more for its own inherent qualities than as a sweetener replacement for sugar, since a manufacturer who replaces sugar with corn sirup (dry basis) for savings in cost, eliminates those savings if he makes any adjustment for the lesser sweetening power of corn sirup. However, if a manufacturer's processes permit him to replace sugar with corn sirup pound for pound, dry basis (making no adjustment for the relative sweetening power of the two products), effective savings can be realized, depending upon the scale of corn sirup purchasing. The savings from tank car purchases of corn sirup are much greater than those from purchases of corn sirup in barrels, and to a lesser extent, are greater than those when purchases are made in other containers. (The buyer's location, as has been pointed out previously, may also have an influence upon his decision as to the purchase of corn sirup for a portion of his sweetener requirements.)

Sugar and Corn Sirup Solids - Price data are available on corn sirup solids only for the years 1947 through 1949. The average quoted prices for sugar and solids, 1947-49 are compared below.

Table 12. - Refined Sugar and Corn Sirup Solids: Prices and Price Differential, 1947-49

Year	Refined Sugar 1/ (dollars per cwt.)	Corn Sirup Solids 2/ (dollars per cwt.)	Price Differential (dollars per cwt.)
1947	8.29	7.63	0.66
1948	7.76	7.26	0.50
1949	7.97	6.93	1.04

1/ Refined Sugar: Gross price, including tax, New York.

2/ Corn Sirup Solids: Price per cwt., carloads, New York.

As stated previously, corn sirup solids contain between 2.5 and 3.5 percent moisture. On this basis, the dry substance of corn sirup solids, where adjustment was made for moisture content, would have cost between $7.11 and $7.18 in 1949 while the differential between sugar and solids would have approximated that of sugar and dextrose. Although the quoted price of corn sirup solids is much higher than that of corn sirup, the dry substance cost is less than that of any corn sirup purchased in barrels in carlot quantities.

FEDERAL AND STATE REGULATIONS

Introduction - Sweetener use in the manufacture of most processed foods is markedly influenced by both Federal and State regulations. The extent of this influence over food manufacturers is of such importance that the various food processors and related industries have recently established, staffed, and financed a Food Law Institute, designed to stimulate basic instruction and research in food laws or regulations as taught at university schools of law. 23/ At first, these regulations, which define the type and frequently the amounts of sweeteners that may be used in commercially prepared foods, leaned heavily in favor of sugar as an exclusive sweetener. The general direction of the changes which have been made in these standards over a period of time has been toward allowance of a much broader range of sweeteners. Although the principal reason for most of these changes has been to permit usage of corn sweeteners, many of the modifications have been much broader in scope. For example, the food laws of many States now permit the use of any "pure, wholesome, and nutritive sweetener."

This chapter refers to two sets of Federal food standards: The permissive standards issued by the Production and Marketing Administration of the U. S. Department of Agriculture, and the mandatory standards administered by the Federal Security Agency's Federal Food and Drug Administration.

In addition, most States and some cities have regulations covering permissible ingredients in certain food products. Some of the State laws pertaining to sweetener use are as complete as those promulgated by the Federal Government, while others contain only general provisions on this subject. A few States in the latter category provide no funds for the enforcement of such laws.

The Federal food and drug laws generally exert a greater influence than U. S. Department of Agriculture or State regulations on a manufacturer's choice of kinds and amounts of sweeteners used in canned fruits and vegetables, preserver's items, and sweetened condensed milk. The Department of Agriculture's permissive standards are now operative in controlling a choice of sweetener in tinned and frozen products that are not covered by Federal food and drug regulations. State regulations are more influential in affecting sweeteners used for such products as ice cream and soft drinks which are as yet not covered by either of the two types of Federal standards. 24/ The roles which the regulations of the Food and Drug Administration, the Department of Agriculture, and selected States play in influencing types and amounts of sweeteners used in processed foods are discussed separately below.

23/ Food Field Reporter, December 5, 1949, page 38.

24/ In order that those who manufacture products covered by the Food, Drug and Cosmetic Act comply fully with the regulations, they should read the standards in complete context, rather than rely on the summarizations and interpretations given here.

Food and Drug Administration Standards

Canned fruits [25] - The canned fruits for which Food and Drug Administration standards are in effect include canned peaches, apricots, pears, cherries, and fruit cocktail. For each of these products, optional packing media and the permitted range in density of packing media are prescribed. For all these products except fruit cocktail, ten optional packing media are allowed as follows:

(1) Water.
(2) Fruit juice (peach, apricot, pear, or cherry juice to which no water has been added).
(3) Slightly sweetened water.
(4) Light sirup.
(5) Heavy sirup.
(6) Extra heavy sirup.
(7) Slightly sweetened fruit juice.
(8) Light fruit juice sirup.
(9) Heavy fruit juice sirup.
(10) Extra heavy peach juice sirup.

For each of these packing media from 3 to 10, there is established a permitted range in density, as measured by a Brix reading 15 days or more after the fruit is canned. The range in density allowed for each of the packing media varies somewhat by type of fruit. However, the following densities permitted for canned peaches are typical:

Number of Packing Medium	Density in Degrees Brix
3 and 7	Less than 14°
4 and 8	14° or more but less than 19°
5 and 9	19° or more but less than 24°
6 and 10	24° or more but not more than 35°

No sweeteners are used in optional packing media 1 or 2. Sweeteners are used with water as the liquid ingredient in media 3 to 6, inclusive, and with the juice of the particular fruit as the liquid ingredient in media 7 through 10. Packing media 3 to 6, inclusive (those with water as the liquid ingredient), may be prepared with any of the following sweeteners:

(1) 100% sugar or invert sugar sirup. [26]

25/ Based on Federal Security Agency, Food and Drug Admn. Definitions and Standards for Food, SRA, FDC-2, Rev. 1, Dec. 28, 1948, pp. 34-47; 60-68.

26/ Invert sugar sirup is defined as "an aqueous solution of inverted or partly inverted, refined or partly refined sucrose, the solids of which contain not more than 0.3 percent by weight of ash, and which is colorless, odorless and flavorless except for sweeteners." This, of course, would include invert sugar and all grades of liquid sugar which meet the ash requirement since even the sucrose type liquid sugar is partially inverted.

(2) Sugar and dextrose, with not more than 1/3 the solids as dextrose.

(3) Sugar and corn sirup or corn sirup solids with not more than 1/4 the solids as corn sweetener.

(4) Sugar, dextrose, and corn sirup, or corn sirup solids, with twice the weight of the dextrose solids plus three times the weight of the solids of the corn sirup or corn sirup solids not more than the weight of the solids of the sugar. (From 1/4 to 1/3 may be in the form of corn sweetener, depending on the relative amounts of dextrose and corn sirup or corn sirup solids. The weight of the solids of the corn sweetener would approach 33 percent when practically all of it is dextrose and 25 percent when it is largely corn sirup or corn sirup solids).

Packing media 7 to 10, inclusive (these with the natural fruit of the juice as the liquid ingredient) may be prepared with any of the above sweetening ingredients except that no invert sugar sirup may be used and corn sirup may be used only in the dried form (corn sirup solids).

The Food and Drug Administration regulations with respect to labeling requirements for canned peaches, specify that the name of the sirup density as a packing media be indicated. However, there are no requirements with respect to identifying the particular sweeteners used.

Canned vegetables - In canned vegetables, except for those few for which specific standards exist, sweeteners are used essentially as seasoning agents. Food and drug regulations permit the use of either sugar or dextrose, or both, for this purpose, without any limitations on amounts and with no requirements for label declaration.

Fruit preserves, jams, jellies, butters [27]/ - Food and Drug regulations for pure fruit preserves, jams and jellies require that they consist of not less than 45 parts by weight of fruit ingredients to each 55 parts by weight of permitted sweeteners. The following optional saccharine ingredients are permitted:

(1) Sugar
(2) Invert sugar sirup
(3) Any combination of sugar and invert sugar sirup
(4) Dextrose in combination with either sugar or invert sugar sirup, or both.
(5) Corn sirup in combination with either sugar or invert sugar sirup, both sugar and invert sugar sirup, or with sugar, invert sugar sirup, and dextrose. In these combinations the solids weight

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27/ Ibid. pp. 47-54.

of corn sirup cannot exceed half the total solids weight, and the solids weight of each other component of the combination cannot be less than 10 percent of the total solids weight.

(6) Honey

(7) Any combination of honey with sugar or invert sugar sirup, or both, in which the solids weight of the honey is not less than 40 percent of the total solids weight and the solids weight of each component other than honey is not less than 10 percent of the total solids weight.

When honey is the sole sweetening agent (option 6 above), the label must bear the statement "Prepared with honey." When either corn sirup or honey is used in combination with other sweeteners (options 5 and 7 above), the label must bear the names of the component sweeteners in order of predominance by weight.

Food and drug regulations provide that fruit butters be prepared with not less than 5 parts, by weight, of fruit to each two parts, by weight of sweeteners. 28/

The optional sweetening ingredients are:

(1) Sugar
(2) Invert sugar sirup
(3) Brown sugar
(4) Invert brown sugar sirup
(5) Honey
(6) Corn sirup
(7) Any combination composed of two or more of optional sweetening ingredients 1, 2, 3, 4, 5, and 6.

(8) Any combination of dextrose and optional sweetener ingredients 1, 2, 3, 4, 5, 6, or 7. If honey is a component, the weight of its solids may not be less than 40 percent of the total solids weight of the combination.

When honey or corn sirup is used as the single sweetening ingredient, (options 5 and 6 above), the label must bear the statement "Prepared with Honey" or "Prepared with Corn Sirup," as the case may be. When corn sirup or honey, or both, are used in combination with other sweetening ingredients, all the components of the combination must be listed on the label in order of predominance by weight.

28/ Fruit butters may be made without sweeteners if the seasoning ingredient is composed of fruit juice or diluted fruit juice, or concentrated fruit juice in a quantity not less than one-half the weight of the optional fruit ingredient.

Cocoa and chocolate products [29] - Insofar as confectionery items are concerned, the Federal food and drug standards relative to sweeteners apply only to the manufacture of cocoa and chocolate products. The following discussion refers to the standards for sweet chocolate and sweet chocolate coatings. Either all sugar, or combinations of sugar with either or both dextrose and corn sirup solids are permitted to be used in these products, with no requirements for declarations of identity on the label for any of these combinations. There are, however, limitations on the amounts of dextrose and corn sirup solids which may be used in combination with sugar. These limitations are as follows: (1) Sugar and dextrose - not more than 33 percent of the total sweetener as dextrose; (2) Sugar and corn sirup solids - not more than 25 percent of the total sweetener as corn sirup solids; and (3) Sugar, dextrose, and corn sirup solids - "...three times the weight of the solids of the dextrose used plus four times the weight of the dried corn sirup used is not more than the total weight of the solids of all the saccharine ingredients used." This means that when the 3 sweeteners are used in combination, the weight of dextrose plus that of corn sirup solids would approach 33 percent when practically all the corn sweetener is dextrose and 25 percent when it is largely corn sirup solids. Only the anhydrous type of dextrose may be used. Honey, molasses, brown sugar, or maple sugar may be used for flavoring purposes.

Sweetened condensed milk [30] - The Food and Drug Administration defines sweetened condensed milk as "...the liquid or semi-liquid food made by evaporating a mixture of sweet milk and refined sugar (sucrose) or any combination of refined sugar (sucrose) and refined corn sugar (dextrose) to such point that the finished sweetened condensed milk contains not less than 28.0 percent of total milk solids, and not less than 8.5 percent of milk fat."

The only stipulation with respect to the quantity of sugar or sugar and dextrose which may be used is that it be sufficient to prevent spoilage. Condensed milks may also be made with corn sirup or corn sirup solids either alone or in combination with sugar. However, these condensed milks cannot be called "sweetened condensed but must have the following nomenclature:

(1) If all corn sirup or corn sirup solids are used:

(a) Corn sirup condensed milk,
(b) Condensed milk with corn sirup, or
(c) Condensed milk prepared with corn sirupsk and

29/ Ibid. pp. 7-12.
30/ Ibid. p. 30.

(2) If corn sirup or corn sirup solids are combined with sugar:

(a) ___percent corn sirup solids___percent sugar condensed milk,
(b) Condensed milk with___percent corn sirup solids, ___percent sugar,
(c) Condensed milk prepared with___percent corn sirup solids,___percent sugar.

Frozen fruits 31/- Federal food and drug standards currently are being formulated for frozen fruits. While there are two types of containers - household pack and bulk-size (commercial)--we are concerned here primarily with the household pack. When frozen fruits are to be put up with a dry pack, the proposed standards would allow four options in sweetening ingredient or ingredients, as follows:

(1) Sugar only
(2) Sugar and dextrose
(3) Sugar and corn sirup solids
(4) Sugar, dextrose, and corn sirup solids

In combination 2, 3, and 4, the weight of the sugar shall be not less than two-thirds the total sweetener weight. When a liquid pack is used for frozen fruit, the proposed standards would allow use of these sweeteners: Sugar, invert sugar sirup, dextrose, corn sirup solids, corn sirup, and glucose sirups. When a liquid pack is made by using one or more of these optional sweeteners, for most products the packer would have a choice of four types of sirups with solids content, in degrees Brix, as follows:

(1) Heavy sirup - not less than 60°
(2) Medium sirup - 50° to 59.9°
(3) Light sirup - 40° to 49.9°
(4) Sweetened water - 30° to 39.9°

For 1, 2, and 3 the total solids content shall consist of not less than two-thirds by weight of sugar or invert sugar, or any mixture of these two sweeteners.

For the commercial packs 32/ of frozen fruits, the proposed Food and Drug standards would require label declaration both as to the fruit-to-sweetener ratio and as to identity of sweeteners used. They also would require listing the sweeteners in descending order of predominance by weight. For packs destined for household use, the proposed regulations prescribe label identification of sweetener used and indication of whether a liquid or dry pack was used.

31/ Federal Security Agency, Food and Drug Administration, Frozen Fruits, Notice of Proposed Rule Making with Respect to Definitions and Standards of Identity and Standards of Fill of Container, Federal Register Vol.15, No.192. October 4, 1950, pp. 6674-86.

32/ Packs used by bakers, ice cream producers, etc. in making products containing frozen fruits.

Ice cream, sherbets, and ices [33] Pursuant to notices published in the Federal Register of November 1 and November 19, 1941, a hearing was held on proposals to adopt definitions and standards of identity for ice cream, frozen custard, sherbet, water ices, and related foods. A tentative order was not published because the War Food Administration had issued regulations restricting the use of some of the raw materials used in the preparation of the above-described foods. Further action relative to the promulgation of definitions and standards of identity for these foods was deferred until recently.

As proposed in the notice of hearing, the suggested standards would permit these sweeteners in ice cream: sugar, invert sugar sirup, dextrose, corn sirup, corn sirup solids, maple sirup, maple sugar, honey, brown sugar, and molasses. In sherbets and ices, only these sweeteners would be permitted: sugar, invert sugar sirup, dextrose, corn sirup, and corn sirup solids. These sweeteners could be used singly or in any desired combination of two or more.

As now drafted, the suggested standards would not set a maximum or minimum sweetener content for any type of frozen dessert. However, in the case of ice cream, the minimum total solids content, the weight of the finished ice cream per gallon and the minimum butterfat content are specified, and, under "Findings of fact," minimum nonfat milk solids are taken into consideration. Thus, for ice cream containing a minimum total solids and a minimum butterfat content, a maximum nonfat milk solids content would tend to create a lower limit for total sweetener content since this would be the residual portion of total solids remaining in the average ice cream mix.

Bread [34] - The proposed Food and Drug Administration standards for bread provide that in preparing a kneaded yeast-leavened dough, the following optional sweeteners may be used: sugar, invert sugar, invert sugar sirup, light-colored brown sugar, refiner's sirup, dextrose, honey, glucose sirup, corn sirup, corn sirup solids, nondiastatic (dried) malt sirup, molasses (except blackstrap). The proposed standards would permit the use of combinations of two or more of these sweeteners without limiting the percentage amount of any one sweetener, and would establish no minimum amount of total sweetener.

In summary, Federal food and drug regulations always permit the usage of sugar as 100% of the total sweetener but they often place limitation on the amounts of corn sweetener allowed. A summary of the effect of Food and Drug Administration regulations on usage of dextrose, corn sirup, and corn sirup solids is as follows:

33/ Federal Security Agency, Food and Drug Administration. Ice Cream, Frozen Custard, Sherbet, Water Ices, and Related Foods; Definitions and Standards of Identity. Notice of Hearing. Federal Register Vol. 15, No. 152, Aug. 8, 1950 -pp. 5112-21.

34/ Federal Security Agency, Food and Drug Administration. Bakery Products; Definitions and Standards of Identity. Notice of Proposed Rule Making. Ibid. pp. 5102-12.

	Dextrose	Corn Sirup	Corn Sirup Solids
Canned Fruits	May be used only in combination with sugar or sugar and other corn sweeteners.	May be used with sugar or sugar and other corn sweeteners	May be used only in combination with sugar or sugar and other corn sweetener.
	May not be more than 1/3 of total sweetener	May not be more than 1/4 of total sweetener. Cannot be used when fruit juice is the liquid ingredient.	May not be more than 1/4 of total sweetener.
Canned vegetables	No limitation	Not permitted	Not permitted
Pure fruit Preserves, jams and jellies	May be used only in combination with sugar or sugar and corn sirup.	May be used only in combination with sugar or with sugar and dextrose.	Not permitted
	No maximum % of total sweetener specified.	May be not more than half the total sweetener.	
		When used, label identification of all sweeteners in order of predominance is required.	
Fruit butters	May be used in combination with sugar or corn sirup, with no maximum percentage limit of total sweetener specified.	When the only sweetener used, label must say "Prepared with corn sirup." When used in combination with other sweetener, all must be stated on label in order of predominance.	Not permitted.
Cocoa & chocolate	Must be anhydrous	Not permitted	May be used only in combination with sugar or sugar and dextrose and may not be more than 1/4 of total sweetener.
	May be used only with sugar or sugar and corn sirup solids and may not be more than 1/3 of sweetener.		

	Dextrose	Corn Sirup	Corn Sirup Solids
Sweetened condensed milk	May be used only in combination with sugar with no limitation on percentage which it may constitute of total sweetener	Not permitted	Not permitted
Frozen fruits (proposed)			
Dry Pack	May be used in combination with sugar up to 1/3 of total sweetener. May be used in combination with sugar and corn sirup solids, but sugar must be not less than 2/3 of total	Not mentioned with dry pack.	May be used in combination with sugar but cannot exceed 1/3 of total sweetener. May be used in combination with sugar and dextrose but sugar must be not less than 2/3 of total sweetener. When fruit is packed in bulk-size containers to be used in the preparation of other food products, may be used as all the sweetener.
(Glucose Sirups)	Same as for corn sirup.		
Liquid Pack	May be used in combination with sugar up to 1/3 of total sweetener. May be used in combination with sugar and corn sirup solids, but sugar must be not less than 2/3 of total sweetener.	May be used in combination with sugar up to 1/3 of total sweetener. When fruit is packed in bulk-size containers to be used in the preparation of other food products, corn sirup may be used as all the sweetener.	May be used in combination with sugar, but sugar must be not less than 2/3 of total sweetener.
Frozen Desserts (Suggested)	No limitation	No limitation	No limitation
Bread (Proposed)	No limitation	No limitation	No limitation

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Although Federal food and drug regulations seem to limit corn sweetener usage to many food industries, such limitations are, in general, well within the accepted practices of the various sweetener-using industries. There are instances, however, where all or certain portions of an industry would like to see certain provisions altered. A case in point is the labeling requirement for corn sirup use in preserved items. Many preservers would prefer to have the regulations permit 25 percent corn sweetener without label declaration than 50 percent with label declaration. 35/ It will be noted that the regulations are generally much more restrictive with respect to the usage of corn sirup than for dextrose. This restrictiveness on corn sirup is reflected either in disallowing its use in a product or by permitting it to be used but as a lower percentage of total sweetener than is allowed for dextrose. Also, labeling requirements for corn sirup are somewhat more stringent than for dextrose, specifically regarding preserves and condensed milk.

United States Department of Agriculture Standards 36/

The standards for grades of the U. S. Department of Agriculture, Production and Marketing Administration differ from Food and Drug Administration regulations in that they are permissive rather than mandatory. If, however, a food processor packs his product under continuous Government inspection and uses the U. S. grade statements on the labels on his product, he must, of course, meet the requirements of the grade stated on the label. The U. S. Department of Agriculture's permissive standards do not conflict with the Food and Drug Administration's mandatory regulations.

The USDA standards may be divided into five groups, insofar as sweetener usage is concerned: Products for which Food and Drug Administration Standards are accepted, products with or without any sweetener, products with or without sirup, with or without sugar or sirup, and with or without sugar.

Products for which Federal Food and Drug Standards are Accepted - For many products, sweetener provisions of the USDA standards are merely an acceptance of Food and Drug Administration regulations. Included in this category are almost all the preserved items and the following canned fruits and vegetables: Apricots, cherries, fruit cocktail, peaches and pears; beans, beets, carrots, corn, succotash and sweet potatoes.

Products With or Without any Sweetener - The U. S. Department of Agriculture standards allow many products to be processed with or without any sweetener. Canned items in this category include: Grapefruit juice, orange juice, orange and grapefruit juice, tangerine juice,

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35/ At the January 1951, Food and Drug hearings on the standards for preserves, this recommendation was made for changing the existing standards.

36/ This discussion of USDA standards is based on standards in effect on January 1, 1951. Full information with respect to the standards for any product can be obtained from Processed Foods Standardization and Inspection Division, Fruit and Vegetables Branch, PMA., USDA, Washington 25, D. C.

pineapple and pineapple juice. Frozen items include: Berries, (strawberries, raspberries, blackberries, boysenberries, etc.), cherries, grapefruit, pineapple and concentrated orange juice. No restrictions are placed on the kind of sweeteners which may be used in either the canned or frozen items which U. S. Department of Agriculture standards allow to be packed with or without any sweetener. No amounts of sweeteners are specified for the frozen items. A minimum brix is established for each grade of the canned juices, and certification to grade is required to indicate the density found to be present in the samples tested.

Products With or Without Sirup - USDA standards permit several products to be processed "with or without sirup," with the sirup not defined as to type or composition. These include canned apples, figs, and plums. Except for apples, the standards specify minimum brix for sirups of varying density which may be used for these products.

With or Without Sugar or Sirup - For a few frozen items, U. S. Department of Agriculture standards specify, with respect to sweeteners, that they be processed "with or without sugar or sirup." Included in this group are apples, apricots, peaches, and rhubarb. Since sugar is not defined as to source or type, and since no restriction is placed on the type of sweetener placed in sirup, U. S. Department of Agriculture standards affect the type of sweetener used only to the extent that they should comply with requirements of the Food and Drug Administration.

With or Without Sugar - For a few products, the Department of Agriculture standards formerly specified that they be processed "with or without sugar," and sugar was defined as sucrose. These included canned blackberries, blueberries, raspberries, grapefruit, grape juice, and peas. Use of any corn sweetener was thereby prohibited in these products by Department of Agriculture standards. However, the term "sugar" has been changed in some instances to read "sweetening ingredient."

State Food Regulations

Most States have food laws or regulations, applicable to specific food products processed for sale within the State, which contain certain provisions with respect to types or amounts of sweeteners used. These laws may be supplementary to or in lieu of Federal regulations for a given product, or may be in direct opposition to Federal standards. If no Federal standard exists for a specific product, the State laws form the basis for establishing sweetening requirements, even if the products enter interstate commerce.

In connection with this study, a resume has been made of the sweetener provisions of food standards for the following States: California, Colorado, Georgia, Illinois, Iowa, Louisiana, Massachusetts, Michigan, Mississippi, New Hampshire, New Mexico, New York, Ohio, Oregon, Pennsylvania and Wisconsin.

In instances where a food product is covered by a Federal food and drug standard, the majority of these States were found either to adopt those standards or to make it permissive for administrative officers to use them as a basis for enforcement. A few States have little, if any, published State regulations and rely almost completely on Federal regulations. If most of the processed foods consumed in a State are produced outside of such State (and consequently fall under the Federal standards because of their entering channels of interstate commerce), there is little necessity for State regulations. New Mexico is a good example of a State in this category. 37/

States in which a large volume of sweetener-containing foods are manufactured, may have a similar dearth of their own laws relating to the processing of foods simply because the Federal standards have been accepted as the basis for State regulations over such a long period of time. New York is a good example of this type. 38/ Two of the 16 States, Pennsylvania 39/and Wisconsin, 40/ do not accept the Federal Food and Drug standards, decreeing that only statutes passed by their own regulatory authorities are valid within their borders.

A few others have no provisions in State laws for accepting or rejecting the Federal standards.

Several interesting examples of inconsistency occur in the State food regulations studied. In one State the regulations prescribe that no food regulation in the State can be more stringent than, nor conflict with, the Federal food and drug standards, but at same time, another part of the statutes in force prescribe that the State enforcement agency is required to accept the Federal food and drug standards except where they conflict with the State law. In another case, a State's food regulations of 1942 provide that "sugar alone is permitted as a sweetening agent," while its 1948 regulations permit the use of any "pure, nutritious, wholesome sweeteners;" yet both are in effect at the present time. The situation is no doubt resolved by the enforcement of the latter rather than the former regulation.

37/ New Mexico Laws of 1927 as amended, Chapter 97, Section 8A, Paragraph 8; and Section 8E, Paragraphs 1-3, inclusive.

38/ New York Department of Agriculture and Markets. Agriculture and Market Law. Circular 670 - 1943, p. 4, 15, and 16.

39/ Pennsylvania Ice Cream Law, Act of 1933. P.L. 1116 as amended by Act of June 5, 1937, No. 350. P.L. 1672. Sec. 1. Also Pennsylvania General Foods Law, Act of May 13, 1909 (P.L. 520) as amended by the Acts of April 26, 1923 (P.L. 88). May 22, 1933 (P.L. 899) and the Act of June 1, 1937 (P.L. 1127).

40/ See Wisconsin Statutes, 1947, Ch. 97, Dairy Food and Drugs.

Some State laws operate specifically to prohibit the inclusion of certain sweeteners in a product. For example, in Wisconsin where Federal laws are specifically rejected, the State law requires the use of only sugar (sucrose) in canned fruits. Apparently the Wisconsin laws are enforced, since the fruit canners surveyed in that State reported using all sugar. It is interesting to note that in Pennsylvania, where Federal food and drug standards are specifically rejected but where there is no State statute covering canned fruits, the fruit canners surveyed all reported using both dextrose and sugar.

Of all the State regulations governing sweetener use analyzed in connection with this study, those pertaining to ice cream and soft drinks appear to be the most significant in affecting competitive use of sweeteners. This is largely because these products are not yet covered by a Federal food and drug standard. 41/ For the 16 states for which the food regulations were analyzed, a brief digest has been made of the sweetener provision with respect to ice cream and soft drinks.

Ice cream - In New Mexico 42/ and New York, 43/ the laws specify "sugar" but do not specify the type (cane, beet, or corn), while in Massachusetts 44/ sweeteners used in ice cream are limited to sugar only and sugar is defined as sucrose. However, there appeared to be no enforcement of the Massachusetts regulation as 75 percent of all ice cream firms contacted in that State were found to be using one or more of the corn sweeteners along with sugar.

41/ See page 85 for a discussion of the proposed Federal standards for ice cream. There are no proposed Federal standards currently under consideration covering soft drinks.

42/ New Mexico Dairy Commission, New Mexico Dairy Laws; Rules and Regulations governing the Operation of Cream Stations, State Col. New Mexico, Sept. 1937.

43/ N. Y. Dept. Agric. and Mkts. Article 4A of the Agriculture and Markets Law Relating to Frozen Desserts. Circ. 673. Albany. April 1, 1948, Sec. 71A, p.8.

44/ General Laws of Massachusetts - Chapter 94, Section 65G-65S, inclusive, as amended by Chapter 373 of the (Mass.) Acts of 1934.

The Michigan Ice Cream Law specifies that either sugar or honey be used and does not define sugar. However, a Michigan law of 1881 relative to adulterants in food products specifies that no glucose or grape sugar be used without label declaration of kind and amounts of these sweeteners which the food contains. 45/ The latter law has never been repealed. The remaining 12 States expressly permit the use of any of the corn sweeteners as well as sugar.

Most of the State laws governing ice cream and other frozen desserts rarely have anything to say about the percentage of total weight of product which shall be composed of sweeteners. However, the amounts used are controlled indirectly since the minimum weights of butterfat and total solids are usually stipulated. While some State ice cream laws spell out the required minimum percentage of both milk solids non-fat and butterfat, the regulations are more likely to specify the percentage of total weight of product which must be comprised of food solids and the proportion of this which must be butterfat, leaving the balance to be distributed between milk-solids, non-fat and sweeteners at the discretion of the manufacturer.

The minimum percentage of total solids in ice cream usually specified in the State laws analyzed, ranged from 33 to 39 percent, while the minimum butterfat requirements were normally from 10 to 14 percent. There appeared to be no relationship between the minimum butterfat specifications and the amount of sweetener used. That is, whether a State law required 14 percent or 10 percent butterfat did not appear to influence particularly the amount of sweeteners used. Instead, the manufacturers were more inclined to adjust milk-solids non-fat rather than sweetener to stay within the minimum percentage of total solids and butterfat as specified by State law, and to provide the desired balance in the finished product.

In most States ice cream manufacturers are free to utilize any suitable carbohydrate sweeteners - either as a result of new, rewritten, or amended laws containing a liberal list of acceptable sweeteners or the non-enforcement of restrictive laws. Some States are awaiting the promulgation of the Federal law before passing State legislation on the subject, in order that the two may be in agreement. Meanwhile, in many States enforcement is based more on realistic practices in the industry than on adhering strictly to the letter of out-moded legislation.

Soft drinks - The manufacture of soft drinks was not found to be as uniformly covered by State food regulations as was ice cream. Only 6 out of 16 States surveyed were found to have specific regulations

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45/ Michigan Dept. of Agr. Laws Relating to the Department of Agriculture, Lansing. 1943, Act No. 222, p. 139 and Act No. 254, pp. 26-27.

covering permissible or required sweeteners for this type of product. 46/ Others prohibit the use of saccharin in soft drinks while some have general laws pertaining to all food products. All of the State soft drink laws analyzed permit the use of at least one of the corn sweeteners

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46/ Illinois, Louisiana, Michigan, Ohio, Pennsylvania, and Wisconsin. For details of these regulations, see:

a/ Illinois Laws with Regulations and Standards Enforced by the Division of Foods and Dairies of the Department of Agriculture. Chicago. 1949. page 89.

b/ Louisiana State Board of Health. Bottled Water and Other Bottled Carbonated Beverages. Reprint from Quarterly Bulletin. Baton Rouge, September 1945. chap. 4.

c/ Michigan Dept. Agr. Laws Relating to the Department of Agriculture. Lansing. 1943. pages 71-76.

d/ Ohio General Assembly. Amended Senate Bill No. 190. Columbus. May 1949.
Ohio Food and Dairy Laws and Sanitary Regulations and Standards. Amended Regulations 24 and 25. March 18, 1949. page 198.

e/ Pennsylvania Department of Agriculture, Bureau of Foods and Chemistry. Title II, Ch XVI. Standards for Non-Alcoholic and Carbonated Beverages and Still Drinks. Article 1602. Carbonated Beverages and Still Drinks Law. Public Law 730 as amended, Sec. 5.

f/ Wisconsin Department of Agriculture, Wisconsin Statutes 1947. Chapter 97, Dairy Food and Drugs, Sec. 97.09, Regulation of Soda Water Beverages.

though the statutes of Pennsylvania limit their use to dextrose. Of the 6 States having specific regulations containing sweetener use in soft drinks, all except two (Louisiana and Wisconsin) specify the minimum percentage of sweeteners which must be used. The minimum percentages are 8 percent by weight for all the States except Illinois, where only 5 percent is required.

Information obtained from interviews with soft drink manufacturers, and analysis of a representative group of State laws governing the use of sweeteners in these products, indicate that existing legislation on this subject ordinarily does not affect significantly the choice of sweeteners. However, as soft drink standards are rewritten, or as States add a standard covering these products for the first time, the portions describing permitted sweeteners are generally broadened sufficiently to place no restrictions on the use of sugar or any of the corn sweeteners. This breadth of policy frequently is achieved by a general statement in the regulations permitting the use of any pure, nutritious, wholesome carbohydrate sweetener, rather than naming each one specifically. Similarily, where minimum percentages of weight on a dry basis are stipulated, they generally reflect the lowest amounts which have been found by good industrial practice to be consistent with an acceptable product.

SURVEYS OF MAJOR FOOD-PROCESSING INDUSTRIES

Baked Goods

Purpose of Sweeteners in Bread - In bread making, sweeteners are used primarily to facilitate the leavening process through reaction with the yeast. The carbon dioxide gas produced by fermentation raises the dough and is largely instrumental in giving proper volume and texture to the loaf. Flavor, color, and bloom of the loaf result partly from caramelization of the natural and added sweeteners when subjected to oven heat.

William Jago, whose writings on bread-making have been extensively used as tests in this industry 47/, has observed that:

> "If we abstracted all of the sugar contained in dough (and also all substances capable of being converted into sugar by the addition of yeast and water to flour) without touching the other constituents, the addition of yeast would not produce any gas. Everything would remain quiet until the moment when signs of a more or less advanced putrefactions showed themselves. Yeast, on being sown in the solution of sugar and water, sets up fermentation, but in the absence of sugar no fermentation can occur.
>
> ". . . If it (the sugar supply in a mix) is too low, gas supply at the final stages of the process of bread-making will be inadequate, and if too high, there will be excessive maltose and dextrin in the bread, resulting in loaves with high crust colour, bad texture and poor crumb colour, together with gummy streaks and cores in the loaves and, in very bad cases, collapsing of the structure of the loaf."

A rather large part of the sugar used by most bakers in making bread is not retained in the finished product but is lost in the leavening process. It is estimated that from one to two parts of sugar to 100 parts flour are required for the leavening process. Therefore, the residual sugar in the bread is roughly the amount by which a baker's use of sweetener exceeds this amount. It is generally agreed that a sweetener's contribution to sweetness, per se, is not of primary importance in bread baking. However, sweetening agents do contribute to the over-all flavor and aroma of bread, either directly by contributing some sweetness or indirectly through their effect upon other constituents. 48/

47/ Jago, William. An Introduction to the Study of the Principles of Bread Making. (Revised and extended by Daniel, Albert R.) London. MacLaren and Sons, Ltd. 1946. pp. 87,88,104.

48/ Series of continued articles under various headings relating to the Bread Winner 6-8-6 Program, in Bakers Weekly. July 25-October 3, 1949. Kirkland, John. The Modern Baker, Confectioner and Caterer. London. The Gresham Pub. Co., Ltd. New and Rev. Ed. 1927. pp. 48-49.

As technicians of the American Baking Institute pointed out during the interviews, breads can be made without the use of any sweetener, or at least with amounts far below usual baking practices in this country, as witnessed by the excellent breads of most European countries which utilize almost no sweetener in comparison with that used for the American product. However, the natural sugar content of most European flours is sufficient to assure adequate fermentation, making necessary the use of little or no added sweetener. Similarly, it is necessary to add less sugar to American whole grain bread than to white bread, because of the dearth of natural sugars in most types of flours used in the latter. Almost no sugar is required in making rye bread because of the high natural sugar content of rye flour.

Whole grain flours run about 2.6 percent by weight of total sugars - primarily sucrose with traces of dextrose - while white, or patent flours contain only about half that amount. In his discussion of baking principles and practices, Mr. Bennion, one of the well-known British authorities on bread-making 49/, reports that sugar "in the form of sucrose and invert sugar (the latter constituting about 1/10 of the former) are present in most flours to the extent of 1-1/2--2 percent, per 100-lb. sack." British research would indicate that this constitutes ample sugar for the yeast to act upon in producing all of the gas necessary for the proper aeration of bread, both in the dough and the finished loaf. Research in the United States also indicates that North American flours contain anywhere from about 1 percent sucrose and invert sugar in patent flour to 4 percent in the grain and whole wheat flour, the invert sugar content amounting to about 1/10th of the sucrose present. 50/ Bennion points out that flours which contain excessive sugars tend to reduce the water-absorbing power of the dough and exert a softening action on the gluten, whereas flours deficient in sugar (generally these obtained from white wheats), produce bread which is close in texture, deficient in bloom, and bake out to a dull, greyish color unless substances like the malt products, additional sugar, or dextrose are added to the mix to bring out desired baking qualities.

It is necessary for the enzymes used in bread baking to convert the natural or added sucrose and maltose present in a bread mix in invert sugar or dextrose before fermentation can become effective. Of these enzymes, invertase, maltase, and zymase are the most important. Their functions are as follows:

Invertase - changes the sucrose which is present either in the grain itself or as an added ingredient, and which is

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49/ Bennion, Edmund B. Bread Making, Its Principles and Practices. London. Oxford Univ. Press 1929. pp. 9, 10, 13, 14.

50/ Winton, A. L. and E. B. The Structure and Composition of Foods. N.Y. John Wiley and Sons, Inc. 1932. Vol. 1, p. 251.

not directly fermentable by yeast, into invert sugar which is fermentable.

Maltase - converts malt sugar, or maltose, present in the mix into dextrose.

Zymase - A fermenting enzyme that changes the invert sugar and dextrose resulting from the action of invertase and maltase into carbon dioxide gas, alcohol and small amounts of other substances.

While malt as such is not normally a constituent of flour, the latter always contains maltose sugar and enzymes identical or similar to those found in malt. Bakers reported that it is generally added to a dough mix in the form of malt flour or as a concentrated malt product (in sirup or dehydrated form) derived from barley and other grains and possessing either diastatic or non-diastatic properties. (Where it has been prepared at low temperatures, it contains active enzymes and is known as diastatic malt. If the enzymes have been largely killed off from processing at higher temperatures, the malt is referred to as being non-diastatic.) It is used in bread-making to liquefy some of the starch contained in the flour and then convert this liquefied starch into maltose sugar and dextrins, in preparation for the feeding of yeast and its enzymes. Bakers and food technologists indicated that use of both the diastatic and non-diastatic malt sirups in amounts approximating 1 percent of the weight of the dough mix, promotes a vigorous and healthy yeast action in the dough because the maltose sugar released through their presence is fermentable, after conversion to dextrose, and because the soluble proteins and natural mineral salts contained in them serve as yeast nutrients. 51/ These malt sirups, therefore, are said to help produce doughs with good oven spring, and loaves with an even, uniform grain and velvety texture, whose crust is rich in color from ready caramelization and which stay fresh for a long period of time.

The Purpose of Sweeteners in Cakes - In making cakes, the sweetening agents' functions are somewhat similar to those employed in baking breads, in that sweeteners help to provide a leavening effect and control texture, color and crust. However, in cakes their importance as dough conditioning or fermenting agents is secondary to their primary function of providing sweetness and flavor. They also have much to do with the many chemical and physical conditioners which combine to produce a desired quality of product. The amounts and types of sweeteners used have a direct bearing on texture, color, crust, and market value. Some of the sweeteners used in cakes, especially those in sirup form, also impart their own characteristic aroma and taste to the product.

51/ Standard Brands, Inc., Fleischmann Div. Fleischmann's Part in Baking Bread. N.Y. 1947- pp. 3, 13, 14.

Amounts of Sweeteners Used in Breads and Cakes - Before discussing the types of sweetener used in bread and cakes, attention is directed toward the amounts used, somewhat regardless of type. The method commonly used to indicate amounts of sweetener used in baked goods is to express such quantities in terms of the ratio of sweetener weight to flour weight. Using the flour weight as 100, therefore, the sweetener weight can then be expressed in terms of percentages. In Table 13 are summarized the average percentages of sweetener weight to flour weight for the more important types of bread and cakes, as reported by the bakers surveyed in connection with this study.

Bread - It will be noted from Table 13 that the amount of sweetener used in white bread is somewhat higher than in whole wheat and raisin bread and much more than is used for rye bread. As indicated above, one of the principal factors responsible for use of a higher percentage of sugar in white breads is the relatively low natural sugar content of most of the flours from which white bread is made.

The amount of sweetener used in breads was reported by bakers to have a direct bearing upon the volume, symmetry, crust color, cellular structure and texture of the loaf and upon the eating, toasting and keeping qualities of the product. Bread bakers who reported the current use of anywhere from 7-10 percent total sweetener in white breads (17 percent of firms interviewed) indicated that a higher sweetener content in bread improved the texture, color and flavor of the loaf itself, (especially when used in the form of toast) and reduced the time required for proper fermentation of the dough. In this respect, some baking technicians felt that the increased amounts of sugar in bread making provide a greater measure of control for what is known as "fermentation tolerance," or the limits of time during which a dough must be allowed to ferment to insure best results. For instance, in a lean sugar formula, the time of fermentation must be watched very carefully or the volume of leavened dough will be low, the texture coarse, crust color unattractive, flavor and aroma undesirable. In such a situation they termed the dough "critical," meaning that it has a narrow margin of safety within which proper fermentation will develop. On the other hand, if the sweetener content is doubled, without any other change in the formula, they reported that the fermentation of the dough may be stopped at either three hours or four and a half hours with equally good results, because of a considerable extension in fermentation tolerance. 52/

Until the recent war, with the resultant rationing of sugar and allocation of corn to wet millers, bakers had been gradually increasing the sweetener percentage in most breads. For example, at the beginning of the current century the total sweetener content for standard white bread mix was only 1 to 2 percent. By 1940, however, proportions

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52/ Corn Products Refining Co. Sugars in Bread Baking - N.Y. pp. 6, 7.

Table 13.- Sweetener Content of Bread, Rolls, and Cakes, by type, 1948

	Percentage of Weight of Sweetener to Weight of Flour		
	Average	Range	
		Low	High
Bread			
White	6	2	10
Whole Wheat	5	2	12
Rye	2	1	7
Raisin	5	2	16
Rolls	8	2	16
Cake			
Batter 1/	115	95	144
Sponge 2/	161	55	350

1/ Includes Golden, White, Pound, Layer, Fruit, Spice and Butterscotch

2/ Includes Chocolate, Angelfood, Sponge, and Devilsfood

up to 8 percent were usual and 10 percent was not uncommon. This trend toward higher percentages of sweetener, especially in white breads, appears to be a result of a drive for softness and tenderness in bread texture, to make breads more cake-like in character. During the war years, however, the percentage dropped drastically, with 2 and 3 percent being the rule.

The sweetener content of many bread bakers' formulas have been only partially restored to prewar levels. In a recent series of articles 53/, one of the principal trade journals of this industry, "Bakers Weekly," has been urging bakers to use larger amounts of sugar, milk and shortening, not only to feed the leavening process, but to increase the flavor, palatability, and nutritive value of bread, and to produce a softer or more tender texture. The white bread formulas containing higher ratios of sweeteners were consistently scored higher on a basis of symmetry of loaf, bloom, volume, consistency of crust, color of crust and crumb, texture, grain, aroma, taste and eating quality. These results were recently summarized as follows:

> "(1) In all of its characteristics bread shows a marked improvement as the sugar or sweetener content is increased from 4 percent to 8 percent.
>
> (2) The quantity of residual sugar becomes greater, which is reflected most specifically in the color of the crust of the bread and to a lesser measure in the crumb structure.
>
> (3) All of the scoring properties enumerated in the preceding sentence become greater in value as the quantity of sweetener is increased, the bread having the highest sugar content receiving the greatest score value.
>
> (4) The contribution which sweeteners make to the toasting property of bread is very marked; the bread containing the quantity having by far the best color.
>
> (5) There is an appreciable improvement in the softness as well as the tenderness of the bread as the quantity of sugar agents are increased." 54/

Cakes - Prior to 1945-1946, when the first shortenings appeared on the market containing certain types of emulsifying agents designed to

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53/ See footnote 48/

54/ See footnote 48/

make possible the dispersion of a larger quantity of liquid when the sweetener content of a cake mix is increased, it was common for sweeteners to average around 100 to 130 percent of the weight of the flour content in a given recipe. But as a result of these recent improvements in shortenings, as well as improvements which the millers developed in various types of flour that are suited to cake formulas carrying high ratios of sugar, the sweetener content now usually averages from 130 to 160 percent of the weight of the flour. It was not uncommon to find cake-bakers using sweeteners in amounts up to three times the weight of the flour. These increased sweetener ratios not only provide the consumer with a dessert product which cake bakers reported is sweeter in taste, but also one in which the attendant chemical and physical reactions have contributed to producing more tender and delicate texture.

In a series of articles during the summer of 1949 in Bakers Weekly 55/, the results were given of an experiment conducted for high-lighting the

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55/ Glabau, Charles A. Proper Ingredients in High Grade Cake Production, in Bakers Weekly, N.Y. June 27 - Sept. 19, 1949.

proper ingredients necessary to high grade cake production. The amount of sugar used was one of the most important variables. Tests were run on cakes with sweetener contents relative to flour weights as follows: yellow, chocolate and pound, 90 to 130 percent, and angel food, up to 227 percent. The results of these tests indicated that whenever the quantity of sweetener was raised the cakes became better in quality, as measured in terms of superior scores of the judges and taste panels. Scoring was on the basis of the following characteristics: symmetry, bloom, color of crust, volume, consistency of crust, color of crumb, grain, texture, aroma, flavor and eating quality. Generally speaking, the batter type of cake (such as pound, layer or fruit cakes) were reported to carry more sweetener in relation to flour than the sponge type of cakes (such as angelfood, chiffon or chocolate cakes), because of the larger amounts of the improved shortening which the former group customarily contains. During the survey it was pointed out that the wholesale baker's cakes generally contain around twice as much sweetener as their home-made equivalents or those made by small retail bakers who approximate home baking products as closely as possible. One of the principal reasons for this difference is that the wholesale baker's product must withstand longer periods of shelf life, and the increased amounts of sweetener in wholesale products reportedly helped in keeping these cakes fresh over a longer period of time.

Sweeteners Used in the Baking Industry - Bakers use a wide variety of sweeteners. In the sugar group, they utilize not only white granulated, powdered and brown sugar but also smaller amounts of invert, liquid, and occasionally turbinados, in periods of emergency. Corn sweeteners used by this industry include dextrose, regular conversion and high conversion corn sirups, and corn sirup solids. Molasses, honey, and sweetened condensed milk also are used in small amounts.

Under wartime conditions many bakers made use of the glucose sirups derived from wheat, potatoes, sorghum, etc., but have since discontinued their use. Nearly 30 percent of all firms contacted utilized them. These glucose sirups were used in amounts ranging from 15 to 100 percent of total sweetener, when utilized as sweetener and not as flavoring agents. The most popular proportions were 50 to 100 percent of total sweetener content. Bakers complained that these glucose sirups lacked uniformity of quality and produced heavy and soggy bread which had an inferior, tough texture. The color of crust and crumb apparently were not too seriously affected, so long as such sirups were used with moderation. Bakers' experiences during wartime with substitute sweeteners in bread indicate that quite a variety of sweeteners can be used judiciously without serious consequence. There is also considerable flexibility as regard the total quantity of sweetener which may be used.

Sweeteners Used in Bread - Approximately 44 percent of the bread bakers reported using sugar only: 22 percent used corn sweetener only: and 34 percent used a combination of sugar and a corn sweetener. Thus,

sugar was used by 78 percent of these bakers while 56 percent utilized a corn sweetener. (Table 14). With the exception of one firm which reported using corn sirup, the corn sweetener was dextrose. Dry sugar was by far the most predominant type used, as only 3 percent of the bakers reported using liquid sugar in bread. Molasses and honey were the next most popular sweeteners used in breads. About a fourth of the bread bakers reported using some honey and almost 40 percent said they used some molasses. The type of sweetener varied somewhat with the kind of bread being made. For example, the use of sugar or dextrose was most common in making white bread and rolls (Table 15). In making whole wheat and rye breads, there was more of a tendency than in making other types of bread, to use a combination consisting of some molasses.

Sugar Versus Dextrose - In bread baking the principal competition among sweeteners is that between dextrose and sugar. Of the bread bakers interviewed, more than half reported using some dextrose in 1948 and almost three-fourths indicated that they used a proportion of it during the war. Approximately four-fifths of those firms which used dextrose in bread used it as a complete replacement for sugar; the remainder either used equal parts of sugar and dextrose or about one part dextrose to three of sugar.

The consensus of many bread bakers and those research laboratories contacted was that sugar and dextrose react equally well in the fermentation process, and that the consuming public probably could not distinguish between bread baked with dextrose from that baked with sugar. Many bakers indicated a belief that somewhat faster fermentation is effected with dextrose than with sugar. In breads, a considerable proportion of the sweetener used is for the purpose of feeding the yeasts, so that the resulting gas may leaven the dough. Bread bakers were somewhat divided in their opinions with respect to which of these two sweeteners gives a more desirable crust color to the loaf. Many said there was so little difference in the resulting crust color that this had no practical effect on consumer acceptance. Of those expressing an opinion that there was a noticeable difference, those believing that dextrose gave a better color outnumbered sugar's exponents. Many of these who considered that dextrose imparted a better color to both crumb and crust attributed this to the higher degree of caramelization from use of dextrose. On the other hand, those who thought that sugar gave better color considered this to be due to the invert sugar, particularly the levulose, remaining in the dough at the end of the fermentation period.

The principal reason influencing many bread bakers to use dextrose, however, was not that a more desirable product resulted, but that an equally desirable one could be produced at less cost owing to the price differential between sugar and dextrose. Those who used sugar, however, claimed that more dextrose hydrate than sugar was required to give equivalent all-round results.

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Table 14.- Percentage of Bread Bakers 3/ Using Various Sweeteners, by Areas, 74 Firms, 1948

Sweetener	Area					
	New England (percent)	Middle Atlantic (percent)	North Central (percent)	South (percent)	West (percent)	U.S. (percent)
Sugar 1/	50	83	80	85	83	78
Dry sugar 2/	50	83	76	85	83	77
Liquid	25	-	4	-	-	3
Corn Sweetener	50	58	56	52	67	56
Dextrose	50	58	52	52	67	55
Corn Sirup	-	-	4	-	-	1
Molasses	100	67	36	11	67	38
Honey	50	8	48	8	33	26
Malt	25	25	32	11	-	20

1/ Exclusive of Powdered Sugar

2/ Includes both White and Brown Sugar

3/ Includes White, Whole-wheat, Rye, and Raisin Breads and Rolls

Table 15 - Use of Sweeteners, by Type of Bread, 74 Baking Firms, 1948

Sweetener	Percentage of Firms Using Various Sweeteners by Type of Bread				
	White (percent)	Whole Wheat (percent)	Rye (percent)	Raisin (percent)	Rolls (percent)
Sugar	70	72	52	69	52
Dry Sugar 1/	70	70	50	69	52
Liquid Sugar	-	2	2	-	-
Corn Sweetener	54	40	38	46	52
Dextrose	54	40	38	46	52
Corn Sirup	-	-	2	-	-

1/ Includes both White and Brown Sugars.

Corn Sirups - Virtually no recent use of corn sirups in bread making was indicated. However, use during the war of either regular or high-conversion sirups was reported by more than half the bread bakers contacted. Corn sirup solids also were used occasionally by a few plants. Those who used the corn sirups in bread during the years of sugar shortage indicated that up to 50 percent of total sweetener could be corn sirup, with reasonably satisfactory results insofar as texture of the loaf and color of crust were concerned. When higher percentages of corn sirup were used, most bakers felt that they had a tendency to make breads too soggy.

Honey and Molasses - Honey and molasses were popular sweetening agents in about a third of the plants. These sweeteners are used primarily to impart a particular flavor, to give a special color to crust or crumb, 56/ or for the purpose of retaining desired moisture in darker breads, particularly whole wheat or rye. In these types of bread the total sweetener amounts to only 1-4 percent of the weight of flour used, and bakers reported that honey or molasses could be used in amounts up to 100 percent of total sweetener without running into adverse flavor and texture problems.

Sweeteners Used in Cakes - All cake bakers interviewed reported using sugar, and only 28 percent said they made use of corn sweeteners. Approximately a fifth of them used some invert sugar, but only 2 percent reported using liquid sugar. Dextrose and corn sirup were of nearly equal popularity with cake bakers, 15 percent using the former and 18 percent the latter. Only two out of 61 cake bakers reported using both dextrose and corn sirup. The choice between regular and high conversion corn sweetener was about equal, with 8 percent using the regular and 10 percent using the high conversion type. None were using both types. Only two of the cake-baking firms had ever used corn sirup solids, both instances occurring during the period of wartime rationing.

The corn sweeteners, wherever used in cakes, were generally found to be employed as dough conditioners, primarily to increase the moisture-retaining property of the cake, rather than to replace sugar as such. However, the amounts of dextrose (and occasionally high conversion corn sirup) utilized in some instances appeared to be sufficient to constitute competition with sugar. More than one-third of the cake bakers reported that they were more inclined to utilize the less expensive corn sweeteners as dough conditioning agents, in place of liquid sugar or invert sugar, when the price differential between sugar and corn sweetener widened.

Sugar - Bakers reported an overwhelming preference for sugar as the primary sweetener in cake baking. Among the reasons mentioned most

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56/ "Crumb" is the term used by bakers that refers to the "inside" of baked goods, particularly bread and cakes, as differentiated from the outside layer or "crust."

frequently was the greater sweetening power of sugar in comparison with other sweeteners, along with its contribution to desired color, texture, taste, and tenderness of the product. Taste was often considered in conjunction with sweetness, as many bakers indicated a belief that the public has become accustomed to a product with a high degree of sweetness. Furthermore, the psychological association of sugar with a luxury product such as cake is of long standing, and a large number of bakers stated that they were strongly influenced by the apparent fact that all-sugar cakes are closely associated with high-quality cakes in the minds of the buying public.

Next to sugar in fine granulated form, invert sugar is more popular than any of the other sucrose sweeteners in making cakes. Many bakers, especially those using all-sugar formulas, reported using invert sugar in small percentages of total sweetener-rarely over 2 percent - for increasing moisture retention, extending shelf life, and for keeping icings solf over longer periods of time. When used for its hygroscopic and crystallization-controlling properties, invert sugar also has the property of imparting a relatively high degree of sweetness to cakes or icings, where this is desired.

The relatively low percentage of liquid sugar use where this product was available was generally attributed to the expense of installing equipment necessary to handle sugar in this form. Quite a few bakers objected to the excess moisture in liquid sugar which in the usual formulas at least, has to be evaporated in the cake baking process. Small amounts of liquid sugar, however, rather than invert sugar or corn sirups, were occasionally used for improving the moisture retention property of cakes.

Dextrose - Dextrose was reported to be substitutable for up to 25 percent of the sugar in a cake recipe with good results, especially in chocolate cake. Improved color and economy in material cost were given as the principal advantages for its use. Most bakers using dextrose reported that its use was restricted largely to chocolate cakes. However, many of them were found to have experimented sufficiently to be willing to use dextrose in a wider variety of cakes if it became necessary to do so to reduce costs, or if sugar were unavailable. When substituted for more than one-fourth of the total sugar content of a cake mix, dextrose was reported to lessen the sweetness perceptibly. In addition, these larger percentages were said to impair the texture and sometimes impart an off-flavor. The use of dextrose in cake-baking was most common in the Southern States, where nearly one-third of the plants surveyed used it. Usage was least common in the West, where no cake bakers were found to be in favor of it.

Corn Sirup - Almost two-fifths of all the cake makers reported the current use of corn sirups. They used corn sirup in quantities ranging from 5 to 35 percent of total sweetener. Of the corn sirups, the high-conversion type was found to be considerably more popular than the regular

conversion sirups, primarily because of the greater sweetness and property of producing lighter and more tender textures, because of their lower dextrin content. Corn sirups were used as dough conditioners in much the same way as invert sugar, except that larger amounts were used. Bakers reported using it as 10 to 35 percent of total sweetener in cakes. In these amounts it was said to increase moisture retention and extend shelf life. It also was used in icings to keep them soft. The cut-down in sweetness, without the sacrifice of body, which could be obtained from use of corn sirup was reported to be an advantage sometimes. However, the savings realized because of the price differentials between sugar and corn sirup were reported to be the dominant reason for using the latter.

The heaviest geographic concentration of cake bakers who reported the use of corn sirup was in North Central States (See Table 16). The widespread use of corn sirups in the Middle West and the dearth of it in the Seaboard areas may be attributed apparently to the pricing method used for this sweetener. Corn sirup is cheaper relative to sugar in the areas adjacent to point of production (North Central States).

The number of cake bakers reporting the use of corn sirup during World War II (40 percent) increased greatly over those which normally utilized it in peacetime. (See Table 17) Likewise, the amounts of corn sirup in proportion to flour weights were found to be materially increased. As in the case of breads, the wartime replacement of sugar with corn sirup brought the proportions of the latter in many formulas to about double their normal relationships. For instance, the low-conversion sirups were reportedly utilized by many cake bakers during the war for about one-third of the sweeteners and a few reported their use to be as high as 65 percent of total sweetener. The high-conversion sirups, when available, were substituted for sugar to an even greater extent, being used by some cake bakers in amounts up to 90 percent of total sweetener. However, most firms reported wartime usage of this type of sweetener as only about half of total sweetener requirements. The use of sugar and invert sugar in cakes was decreased correspondingly.

The experience which many bakers had with corn sirups during the wartime period has contributed to the continued use of these sirups, but in much smaller amounts, uncer normal conditions. None of the firms reported the use of corn sirup solids in cake baking, although there were no objections to its characteristics as a sweetener. The objection was to the difficulty in handling this sweetener in small lots, because of its hygroscopic nature.

Table 16.- Percentage of Cake Bakers Using Various Sweeteners, by Areas, 61 Firms, 1948.

Sweetener	Area					
	New England	Middle Atlantic	North Central	South	West	U.S.
Sugar	100	100	100	100	100	100
Dry 1/	100	100	100	100	100	100
Liquid	17	-	-	-	-	2
Invert	17	-	27	25	33	21
Corn Sweetener	33	27	32	31	17	28
Dextrose	17	18	5	31	-	15
Corn sirups	17	18	32	-	17	18
Regular	-	-	23	-	-	10
High conversion	17	18	9	-	17	8

1/ Includes both White and Brown Sugars.

Table 17. - Comparative Importance of Regular and High Conversion Corn Sirups in 96 Plants of the Baking Industry, Under Wartime and Postwar Conditions.

Breads	Wartime Conditions		Postwar Conditions	
	Regular	High Conversion	Regular	High Conversion
Plants using corn sirup	51%	18%*	1/	1/
Corn sirup as percentage of total sweetener	5-100%	50-100%	1/	1/
Range				
Most common percentage	100%	100%	1/	1/
Cakes				
Plants using corn sirup	40%	15%*	8%	10%
Corn sirup as percentage of total sweetener	10-85%	20-90%	5-25%	10-35%
Range				
Most common percentage	35%	40%	15%	25%

1/ Only 1 firm reported using corn sirup. This firm used regular corn sirup as 100% sweetener.

* Bakers indicated that the comparative use of high conversion sirups under wartime conditions would normally have been higher than those shown, had they been as readily available as were the regular corn sirups.

THE SOFT DRINK INDUSTRY

The Purpose of Sweeteners in Carbonated Beverages

The two primary functions of a sweetener in a carbonated beverage are to provide sweetness and desired density. A carbonated beverage usually contains a sugar sirup, acid, flavoring, and coloring. The sweetener content constitutes practically all of the soluble solids in a beverage. Thus, the sweetener, an important factor in the resulting taste of a soft drink, also provides body for the finished product.

In bottling a soft drink, a measured amount of the sirup (the "throw") is put into the bottle and purified carbonated water is added to produce the finished drink, the amount of the "throw" for any specified drink and the same size bottle varying inversely with the Baumé or density of the sirup. The method used by a soft drink manufacturer in preparing the flavored sirup from which the final beverage is made has a material influence upon the type of sweetener used. In general, he may follow either of the following two methods:

1. A "simple sirup" 57/ composed of sweetener and water, is first prepared, the proportions of the sweetener to water contingent on the density or Baumé of sirup desired. To this simple sirup is subsequently added the necessary acid, flavoring and coloring for the particular kind of soft drink to be bottled. The resulting product is known as the "flavored sirup."

2. As an alternative, the bottler may prefer to prepare a flavored sirup directly, thus eliminating the first stage of preparing a simple sirup. Direct preparation of flavored sirups is limited, in general, to small-scale operations where storage of a large quantity of simple or flavored sirup is not feasible.

There are two customary ways of preparing a simple sirup: the "cold process" and the "hot process." The former procedure involves the preparation of sirup from sweetener and water at or near room temperature, whereas higher temperatures are used in the latter process. If the bottler uses the cold process method of preparing sirups, he must be extremely careful about the quality of any sweetener which he uses in his soft drinks, as no means of pasteurization is offered by this process per se. An acid may be added to improve keeping quality and give partial inversion of the sucrose in the sirup or other steps may be used to inhibit the growth of organisms. On the other hand, pasteurization of the simple sirup may be obtained by heat with the hot process, either with or without the use of an acid, and this gives the bottler a somewhat wider latitude in his choice of sweeteners. As indicated above (p. 54) the relative solubility of sugar and dextrose varies with the temperature. Dextrose is less soluble

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57/ The term "simple sirup" is, at times, used by the carbonated beverage industry to denote a sirup of the desired stock sirup density made up with sweetener and water only or with an acid added to the mixture. For purposes of clarity, the term "acidified simple sirup" may be applied to such a mixture.

when the cold process is used, although this sweetener is somewhat more soluble than sugar at high temperatures. Accordingly, a manufacturer's choice of sweetener or combination of sweeteners may depend, in part, upon the process he uses in preparing the simple sirup and the density of stock sirup he desires to keep on hand at ordinary room temperature.

Total Sweetener Content of Carbonated Beverages

Soft drink manufacturers reported the use of between 6.0 and 16.7 percent sweetener, by weight, in their products during 1948, depending primarily upon the kind of beverage manufactured. Gingerales, colas, root beers, and like beverages generally require less sugar than the fruit drinks. The sweetener content is found to range from a relatively low sweetener percentage in "dry" products to a higher percentage in "sweet" products. The dividing line of sweetener percentage between "dry" and "sweet" beverages is indefinite and varies by type of drink and by manufacturer.

The total sweetener range for the individual soft drink (as shown in table 18) is not indicative of the average sweetener content in an industry where a change of one percent in the sweetener content can greatly affect the taste or flavor of an individual product. However, the table does show the relatively great variation of sweetener percentages within the soft drink groups and the upper and lower limits of sweetener content for each type of beverage. The extremes of sweetener usage are related in many instances to the type of sweetener or sweeteners contained in the soft drinks.

The variation in sweetener content of the different types of soft drink is apparent if average sweetener percentages are compared. Gingerales have a comparatively low sugar content, with an average of 8.6 percent; colas, cream soda, root beer, lemon, and lime drinks average 11.0 - 11.5 percent, while the other fruit drinks average 12.0 - 13.0 percent. By weighting the averages for individual beverages with the ratio of bottle sales of various flavors of soft drinks 58/, it is estimated that the average sweetener content for all drinks sold in the United States is 11.3 percent.

Footnote 58/ - see following page

58/ Determination of national average of soft-drink sweetener content was arrived at by weighting individual soft-drink averages with the ratio of bottle sales of various flavors of soft drinks, 1948, as follows:

(A) Soft Drink (type)	(B) Average Sweetener Content (percent)	(C) Ratio of Bottle Sales (percent)	(B) x (C)
Carbonated water, club soda	0	1.3	-
Gingerales	8.6	2.4	20.64
Colas and similar drinks	11.0	61.6	677.60
Lemon, lime and lemon-lime combinations	11.5	6.7	77.05
Cream Soda	11.5	1.5	17.25
Root Beer	11.5	3.6	41.40
Cherry	12.0	0.8	9.60
Strawberry	12.6	2.0	25.20
Grape	13.0	4.1	53.30
Orange	13.0	8.9	115.70
All others	12.9	7.1	91.59
Total		100.0	1,129.33

$$\text{National average} \cdot \frac{(B \times C)}{(100)} = \frac{1129.29}{100} = 11.29 \text{ percent}$$

Column (B) obtained from Marketing Research Survey, Sugar Branch, PMA.
Column (C) obtained from American Bottlers of Carbonated Beverages, Bottled Soft Drink Sales, Flavor Ratios, Revised 1949.

Table 18.--Selected types of soft drinks, number of companies reporting sweetener content of each type, and total sweetener range for each type

Soft drink	Companies reporting	Total sweetener range
(type)	(number)	(percent)
Gingerale	36	6.0 - 12.0
Lemon, lime, and lemon-lime combinations	29	6.0 - 15.0
Cream soda	28	6.0 - 15.5
Root beer	37	7.0 - 15.5
Grape drinks	36	7.0 - 16.7
Orange drinks	51	7.0 - 16.7
Cola drinks	31	7.5 - 15.0
Strawberry drinks	16	10.0 - 15.0
Cherry drinks	13	10.0 - 15.5
All types	89	6.0 - 16.7

The Use of Sugar in Carbonated Beverages

The Number of Soft Drink Manufacturers Using Sugar: Soft drinks, other than carbonated water, club sodas, and like beverages are rarely manufactured without use of some form of cane or beet sugar. Of 91 manufacturers interviewed, 73 percent stated that they used 100 percent cane or beet sugar in all beverages which they produced; 12 percent stated that they used 100 percent sugar in most products and a combination of dextrose and sugar in a particular product or products. The remaining 15 percent used a combination of dextrose with sugar in all products which they manufactured. The majority of bottlers in the first group were manufacturing nationally- or regionally-known sirups, concentrates, or soft drinks, while about one-sixth of this group represented small independent bottlers producing only their own beverages. The majority of the second group consisted of smaller type establishments which, as a rule, produced their own drinks but often had the franchise for a nationally-known drink. The last-mentioned group of bottlers consisted primarily of large franchise houses and manufacturers of franchised drinks; only one manufacturer in this group bottled solely his own beverages.

The manufacturers who reported the use of 100 percent sugar in all products at the time of this survey indicated that they had used other types of sweeteners during the war only, when sugar was rationed, and some of this group stated that they had cut production during the war rather than use a sweetener other than sugar. Except for one manufacturer who reported using corn sirup in draft root beer, the companies included in the last two groups above reported using no sweeteners at the time of this survey other than sugar and dextrose.

The greater majority of the bottlers interviewed used granulated sugar. However, almost 20 percent of them had installed liquid sugar facilities in their plants. This compares with 1949 liquid sugar deliveries equal to 17 percent of total direct sales of sugar to beverage manufacturers. 59/ More than 15 percent of the bottlers were either too small for liquid sugar installation, or the initial cost of installation overshadowed the possible savings and convenience of operation. Several were averse to using liquid sugar because of the greater danger of mold growth and fermentation as a result of its use. Bottlers using liquid sugar usually install ultra-violet lights in the tanks or use other measures to reduce the possibility of such deterioration.

Reasons for Use of 100 Percent Sugar in Soft Drinks: Of the group which prefers 100 percent sugar in most or all soft drinks, 39 percent mentioned the relatively greater sweetening power of sugar as the reason or one of the most important reasons for such preference. A large number of those mentioning sweetness prefer, or believe that their customers prefer, a relatively sweet finished product. A few stated that, by the use of sugar alone, sweetness was more consistent and easier to control. Approximately 40 percent of the all-sugar users referred to flavor or taste as an

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59/ Sugar Reports No. 7, Sugar Branch, PMA, USDA.

important factor in their choice of sweeteners. The individuals within this group indicated a belief that 100 percent sugar in a product was conducive to better taste, better flavor, or better flavor retention. It was believed by some that only sugar can properly carry the flavor of a soft drink. These bottlers stated that since sugar has no flavor of its own, it cannot affect the individual flavor of any soft drink. Those who prefer 100 percent sugar in a beverage generally felt that enough body or density was given the drink without excessive sweetness. One small group of bottlers specified that 100 percent sugar provided the optimum density, particularly for fruit drinks which contain fresh fruit juices rather than fruit flavorings. In this case, the use of any other sweetener would increase the body too much if sweetness were to be maintained.

The non-sweetening portions of the formulas of a number of manufacturers were said to be geared to use of 100 percent sugar, and consumer acceptance for their product had been developed over a period of time. These bottlers stated that, although a change of sweetener might not produce an inferior soft drink, it might change the established taste of the beverage and could affect consumer acceptance of the soft drink.

Among those manufacturers who use 100 percent sugar in soft drinks, one-half mentioned "quality" of sugar or the fear of fermentation, bacteriological spoilage, or reduced shelf life as considerations in their choice of sweetener. Although sometimes associated with taste or flavor, quality for the most part was applied to the ability of a sweetener to withstand spoilage or fermentation in a sirup or finished beverage.

About 12 percent of the bottlers indicated that they used sugar alone because the differential between sugar and dextrose was not enough to outweigh the technical difficulties involved in handling two sweeteners. Some of this group stated that there was no price advantage in purchasing dextrose, as the greater poundage necessary to maintain sweetness eliminated the savings in price. A relatively small group of all-sugar users indicated that they would use dextrose if the savings in costs were such that the handling of two sweeteners would be warranted. A few reported that they used 100 percent sugar solely because dextrose hydrate was temporarily unavailable in their territory.

More than 19 percent of the all-sugar group indicated that, where dissolving difficulties had been encountered when using dextrose with the cold process, this difficulty was eliminated by a return to 100 percent sugar usage.

Size of plant operation was indicated as an influencing factor in the choice of sweeteners by 21 percent of the all-sugar group who prefer to use sugar alone for one or more of the following reasons:

(1) Barreled sirup is difficult to handle;

(2) Increased labor is necessary to handle two sweeteners; and

(3) The use of two sweeteners promotes the possibility of formula errors in mixing.

The choice of sweetener or sweetener combination by a particular bottler may depend, in part, on whether the company is an independent organization, is subject to parent company control, or produces a franchise drink. Officials of a number of parent companies, franchise houses, and plants producing the soft drinks of such companies stated that the choice of sweetener or sweetener combination in beverages was left to the discretion of the individual bottler. On the other hand, a much larger number of companies in the 100 percent sugar group included companies in whose beverages 100 percent sugar was required or recommended by a parent company or a franchise house. A few of the all-sugar group purchased a finished sirup from a company which preferred 100 percent sugar in its soft drinks, while others were manufacturing a franchise drink in which 100 percent sugar was required by the franchise house. These latter firms were using 100 percent sugar in their own beverages for convenience of handling a single sweetener where their own soft drink production was relatively small.

Use of Dextrose in Carbonated Beverages

Extent of Dextrose Usage in Soft Drinks: Approximately 27 percent of the total manufacturers interviewed reported the use of dextrose in combination with sugar. Nearly 45 percent of these manufacturers used dextrose in a full line of beverages; the majority used dextrose in one or more particular types of beverages.

Fruit drinks 60/, particularly grape-flavored, and root beer, were the relatively more important soft drinks in which dextrose was used by those firms which employed it as a sweetener. However, users of dextrose in fruit drinks represented a smaller proportion of total fruit drink bottlers than did users of dextrose in root beer and colas of total root beer and cola bottlers. Thus, from the standpoint of the total number of manufacturers interviewed, dextrose use in root beer and colas was relatively more important than in fruit-flavored and other beverages. Nearly a third of the root beer manufacturers used dextrose in combination with sugar; nearly a fourth of the cola manufacturers used dextrose in combination with sugar; while about a fifth of the bottlers producing fruit drinks and lemon-lime combinations and 18 percent of the gingerale bottlers used dextrose in those beverages.

60/ Fruit flavors other than lemon or lime.

Sugar-Dextrose Ratios in Soft Drinks: Most manufacturers interviewed stated that, where dextrose is used, it should be employed in combination with sugar. The percentage of dextrose to weight of total sweetener used ranged from 5 to 45 percent. The greatest number of bottlers using dextrose preferred to limit it to from 12 to 25 percent of total sweetener. Only one manufacturer varied his sugar-dextrose ratio by flavor of drink; the remainder of the dextrose users maintained a constant ratio in all types of soft drinks containing dextrose. The upper limit of competition between the two sweeteners may be estimated at 50 percent replacement of sugar with dextrose, since that was the highest percentage of dextrose which soft-drink manufacturers found during the war emergency period could be used and still produce a marketable product. 61/

The types of dextrose used were said to have some effect on the sugar-dextrose ratio in a soft drink. Where dextrose use was reported, the anhydrous type dextrose was generally preferred, because pound-for-pound substitution can be made with this type without lowering the density of the sirup. When dextrose hydrate supplements sugar in a soft-drink formula, and when the sirup Baumé is to be maintained, there must, of course, be an adjustment for the moisture content of the dextrose. Moreover, if sweetness is to be maintained, the relatively lower sweetening power of dextrose compared with sugar must be allowed for when either type of dextrose replaces part of the sugar content.

Advantages of Dextrose: All but one of the soft-drink manufacturers who reported using dextrose in all their beverages and almost half of those using dextrose in some of their products reported that one of the principal advantages accruing from its use was maintenance of body without excessive sweetness. One-fifth of the bottlers using 100 percent sugar in all products stated that where additional body was desired without excessive sweetness in a soft drink, it was advantageous to use dextrose in combination with sugar.

Almost one-half of the dextrose users were in favor of it as a sweetener because it was thought to carry, or bring out, the flavor in a beverage. Dextrose reportedly carries the flavor of fruit drinks well, particularly grape-flavored beverages. One-fifth of the 100 percent sugar users stated that dextrose use resulted in as good a flavor or even a better flavor than that obtained with 100 percent sugar, but they preferred all-sugar for other reasons.

Some bottlers reported that price plays a large part in their choice of sweetener or sweetener combination. Of the total dextrose users, 20 percent combined this sweetener with sugar for savings in cost alone while 40 percent considered price among other factors influencing their

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61/ Although some bottlers used more than 50 percent dextrose in a particular kind of soft drink during the war, this was an emergency measure or an experiment and was discontinued almost immediately after the war.

preference for dextrose. Of the latter 40 percent, almost one-third reported using dextrose for reasons other than price, yet indicated that price could be an influencing factor, that is, if dextrose prices increased significantly or if the differential between dextrose and sugar decreased sufficiently, they might prefer to handle sugar only. These bottlers, therefore, were using dextrose because, among other things, the cost of dextrose was low enough to compensate for the additional inconvenience of handling two sweeteners.

Disadvantages: Where an opinion of dextrose was expressed by non-dextrose users during this survey, one out of four had rejected the use of dextrose primarily because of its lesser sweetening power compared with sugar. A few of the dextrose users also mentioned lesser sweetening power as a disadvantage in the use of dextrose. Of the non-dextrose users who commented on dextrose, one out of four who commented on it reported that the flavor of dextrose itself tended to alter the desired flavor of a beverage. It was noted that a number of these manufacturers had used dextrose as a high percentage of total sweetener content during the war period. Only a few of the present dextrose users mentioned that dextrose affects flavor or taste.

Very few manufacturers mentioned any problems of fermentation, spoilage, or shortened shelf life attributable to using dextrose in soft drinks. A few reported the use of a type of anhydrous dextrose which contained impurities during the war period. A small number of bottlers noted that high-density sirups made with dextrose tended to crystallize when dextrose constituted a high percentage of total sweetener content. A few seemed to think that dextrose caused sedimentation in the finished product. However, the general lack of criticism among the majority of bottlers from the standpoint of shelf life or keeping quality of soft drinks leads to the conclusion that dextrose is generally acceptable with respect to this factor.

More than one-fifth of the total manufacturers interviewed stated that where anhydrous dextrose had been used, dissolving difficulties were encountered, principally with the cold process method of preparation. A few stated that it was necessary, in some instances, to use scalding water in order to melt down a certain type of dextrose purchased during the war period.

A group of 100 percent sugar users emphasized the convenience and economy of handling one sweetener only. A large number of these bottlers were using liquid sugar. If a bottler has installed liquid sugar facilities the chances are greater that he will use all-sugar in his beverages. Only one plant with a liquid sugar installation reported using a combination of dextrose and sugar, and this was only in root beer.

The Use of Corn Sirup and Miscellaneous Sweeteners in Carbonated Beverages

During the sugar control period of World War II, the manufacturers of carbonated beverages, like so many other food processors, turned to a wide variety of sweeteners in order to stretch their available sugar

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supplies. When food regulations or enforcement policies permitted, use was made of many sweeteners which are not ordinarily found in soft drinks during normal times. Supplementary sweeteners included such products as turbinado sugar, refiners' sirup, honey, corn sirup, corn sirup solids, and glucose sirups made from potatoes and wheat.

The greatly expanded demand for bottled beverages during the war and the resultant short period between the time of production and consumption made it much less important to use only those ingredients which would allow a prolonged shelf life without deterioration or fermentation. Some manufacturers maintained high standards of quality even during extreme sugar shortages; others were forced to use the more readily available sweeteners in order to maintain volume of sales. Most, if not all, bottlers have discontinued the use of substitute sweeteners since the rationing period, because of adverse effects upon quality.

Corn sirup unmixed was contained in the wartime soft drinks of over 70 percent of the manufacturers interviewed during this survey. Almost 12 percent of these manufacturers stated that corn sirup did not affect flavor or color and did give body to the beverage. The other 88 percent stated that corn sirup usage was not desirable for the following reasons:

(a) Difficulty was experienced in handling barreled sirup;

(b) Corn sirup affected the flavor and taste of a beverage;

(c) Fermentation was caused by corn sirup;

(d) Corn sirup lacked sweetness;

(e) Mixing and foaming difficulties were experienced; and

(f) Corn sirup affected the color of clear beverages.

Only one manufacturer was using corn sirup--in draft root beer. One other small company was using corn sirup at times, primarily in order to keep a channel of supply open for supplementary sweeteners; secondarily, to reduce costs.

The usual ratio of corn sirup to sugar during the war compared closely with that of dextrose to sugar and was rarely in excess of 25 to 33 percent of the total sweetener content. When sugar supplies were critically low, however, some plants stretched these ratios to 50/50 corn sirup to sugar, and in rare instances, a manufacturer used 100 percent corn sirup.

CONFECTIONERY

Role of Sweeteners in Confectionery

The functions of sweeteners in candy making are to supply sweetness and body and to provide substances for the control of graining and texture of the product. The principal types of sweeteners used are sugar and corn sirup, the primary functions of sugar being to provide sweetness, body, and graining properties, while the essential functions of corn sirup are to control the crystallization, modify sweetness, improve body, texture, or chewiness of the product, and assist in keeping candy moist or extending its shelf life.

When sugar is the only sweetener used, control of inversion is of great importance, and length of cooking time, temperature of the "cook," kind of cooker (open fire, vacuum pan, continuous cooker, etc.), concentration of ingredients, and choice of inverting agent all are factors which can influence the degree of inversion and crystallization and the density, softness, and other properties of the candy. Control of graining in candy is usually obtained by one or more of the following methods: by controlling the temperature and length of time of cooking the batch; using small percentages of certain organic acids, invert sugars, or the enzyme invertase; or by using one of the corn sweeteners, principally regular corn sirup.

The choice of an agent for controlling graining is governed largely by its price and the type of candy being made. Although the use of acids for producing from sugar the desired amount of invert sugar in a batch of candy must be carefully controlled, this method is rather commonly employed for certain types of candy. However, addition to the sugar of predetermined amounts of invert sugar or one of the corn sweeteners is steadily gaining favor. Use of a certain proportion of regular corn sirup probably is the most common method employed to control graining, but high conversion corn sirups and invert sugar are used where a greater degree of sweetness is desired than obtained from the use of regular conversion corn sirup.

Confectioners' Use of Various Types of Sweeteners

Sugar. Each of the 138 manufacturers interviewed were using sugar. None of them were using liquid sugar exclusively, but nine percent reported using both liquid and granulated. Confectioners need a variety of specialty types of granulated sugar, such as coating and sanding sugar, fine and extra-fine granulated, confectioners, and brown sugar. However, liquid sugar appears to be gaining in popularity in those areas where it is generally available. For example, a third of the firms interviewed in the New England area said that they were using liquid sugar. Liquid sugar lends itself to the manufacture of many types of confectionery, in that corn sirup ordinarily is used as a portion to total sweetener and it

is physically easier to handle two liquid sweeteners than one liquid and one dry. However, the necessity of cooking for a longer time or to a higher temperature, in order to eliminate the excess water, is one of the objections to liquid sugar use by many confectioners.

A few confectioners, especially in the Chicago area, reported using one or more of the direct-consumption types of sugar. In fact, two firms reported using only sugar of this type. Normally, however, those confectioners who make a varied line of products use these sugars only to the extent of 25 to 40 percent of the total sugar content of a candy formula, or only in the dark-colored type of confections, molasses-type candies, and certain grades of chocolate. Objections to turbinados, for example, are based largely on the darkening or discoloration which they give to clear candy pieces, the molasses flavor imparted, the tendency to make the batch foam, and the variation in quality of this sugar. When direct-consumption types are used in place of fully refined sugar, the reason usually is that they cost less.

Corn Sweeteners. Although they have long been used in volume by the confectionery industry before the war, corn sweeteners came into even greater prominence during World War II. Of all the confectioners interviewed in different parts of the United States, 93.5 percent used corn sweeteners of one or more types. By geographic regions, those using corn sweeteners ranged from 100 percent in New England and the South, to 87.5 percent in the West.

The order of importance of corn sweeteners in the confectionery industry, based on quantities used, is (1) regular corn sirup; (2) high-coversion corn sirup, and (3) dextrose. The percentages of confectioners in each major geographic area using each of these types of corn sweeteners are given in Table 19. Preference is heavily in favor of regular corn sirups, more than 62 percent of all the firms interviewed using it as their sole corn sweetener, and an additional 27 percent using it in combination with another corn sweetener. Less than five percent of the firms used high-conversion sirups as the sole corn sweetener, while none of them used dextrose as the only corn sweetener.

Corn sirup solids were used, to some extent, during the war period. This sweetener was used then by 12 percent of the candy makers as a substitute for corn sirup on a pound-for-pound basis, up to 20 percent of the corn sirup requirements in the formula. No plant visited, however, reported its current usage. The principal objection to corn sirup solids was based on its cost and the difficulty of handling this product in less than full-bag lots, since the remaining portion rapidly became sticky.

Other Sweeteners. Limited amounts of other sweeteners are sometimes used and such circumstances as inadequate sugar supplies sometimes dictate greater than normal usage of them. For example, small amounts of honey, molasses, and maple sugar are used primarily as flavoring agents rather than for sweetness. Sweetened condensed milk is often

used although the principal sweetener it contains is that agent used to process the milk rather than the lactose content. This product is often used in such candies as creams, nougats and caramels to supply some of the sweetness, especially when there is a companionate need for milk in the confection.

During the period when sugar was rationed and corn sweeteners were not available in sufficient volume to meet consumer demands, a number of substitute sweeteners were used, such as wheat glucose, potato glucose, maltose sirup, and sorghum sirups, refiners' sirup, and sugar-cane sirups. Confectioners now have abandoned the use of such sweeteners for reasons of non-uniform quality, difficult handling, and greater costs.

CHOICE OF SWEETENER USED

The choice of sweetener, or combination of sweeteners, depends on the physical characteristics inherent in each, differences in delivered prices, type of candy being produced, type of market for which the product is designed, and the methods of production involved. The proportion of the various sweeteners used and the range of substitutibility vary greatly, depending upon the kind of confectionery item produced. Accordingly, a detailed discussion of the extent and nature of the competition between sweeteners must necessarily give consideration to the specific type of product. The confectionery items have been grouped into eleven major categories, as follows: hard candy, fondants, creams, nougats, caramels, gums, jellies, marshmallows, fudge, chocolate, and chewing gum. Before discussing each of these types more fully, however, a few general principles relative to competition between sugar and the corn sweeteners in the confectionery field should be stated. The two primary areas of competition are: (1) sugar vs. corn sirup, and (2) sugar vs. dextrose.

Sugar vs. Corn Sirups

Corn sirups are used primarily to control crystallization and texture. They also aid in regulating the sweetness or taste of the product, and help to maintain the desired moisture content. Corn sirup commonly is used in lieu of an acid or invert sugar. In making most candies with an all-sugar formula, some inversion is necessary in order to control graining, but control of crystallization and texture can often be achieved more economically with corn sirup, the survey showed. Corn sirup has the added advantage of being in a form ready for use without further treatment, thereby making for simplicity of operations and better control over the production process.

For each confectionery item, there is a range in the proportion of corn sirup to sugar which may be used, and in some instances an area in

which the proportion can be varied with little or no apparent effect upon quality. Confectioners have found that in most items it is necessary to use some corn sirup or some other agent to control crystallization and provide the desired texture, and that more may sometimes be used without undue adverse effects upon quality.

The decision to use the minimum or maximum amount of corn sirup in a formula is dependent largely upon the market for which the candy is manufactured and the price differential between sugar and corn sirup. 62/ As the price differential increases, the confectioner feels encouraged to use as much corn sirup as possible without too great sacrifice of quality. However, the extent to which changes in the differential cause changes in formulas varies considerably among confectioners. A few are quite sensitive to small changes in the differentials, while others prefer not to change their formulas unless the spread is considerably widened and has remained wide over a rather long period of time. Some confectioners are reluctant to change the proportions of sugar and corn sirup to take advantage of price changes because of the physical problems associated with changing formulas, and the fear of adverse consumer reactions. In some cases confectioners are already using either the minimum or maximum corn sirup and cannot readily adjust their formulas to take advantage of price changes without materially affecting quality.

There appears to be no specific dollars and cents spread between sugar and corn sirup which would encourage the use of either more or less corn sirup. In other words, confectioners have not geared their formulas to any specific differential between sugar and corn sirup. Before changing a formula to take advantage of a price change, many confectioners weigh the advantages which they will gain by cutting costs with the probable disadvantage which might follow from alteration in quality. For example, a confectioner might be using 70 percent sugar and 30 percent corn sirup in an item when sugar is 8 cents and corn sirup is 6 cents. His per-pound sweetener costs would then be 7.40 cents. If the price of sugar advanced to 6.5 cents and corn sirup remained unchanged, his per-pound sweetener costs, using a 70-30 formula, would be 7.75 cents. By changing his proportions of sweeteners to 60 percent sugar and 40 percent corn sirup, he would be able to reduce his per-pound sweetener costs to 7.50. However, a confectioner would need to consider whether such a change in sweetener ratios might affect adversely the consumer-appeal of the item, resulting in a drop in sales, or requiring a decrease in the selling price of the item. The proportions which the price differential between sugar and corn sirup are of the actual prices of these sweeteners is important as well as the differential itself. For example, a two-cent differential is much more apt to encourage maximum corn sirup usage when the actual prices are two and four cents than when they are six and eight cents. The pressure of all ingredient, production, and marketing costs on the selling price of an item also materially affect the extent to which confectioners change the proportions of sugar and corn sirup to take advantage of changes in the differential. For example, if other costs remain high at the same time the selling price of the item is falling, a spread in the differential is apt to encourage greater use of corn sirup.

62/ For detailed discussion see section on Price Relationships.

Low-cost types of confectionery items produced for certain types of markets usually have larger amounts of corn sirup than similar items produced for a different type of trade. One reason for this, of course, is that costs must be kept to a minimum in items selling for low unit prices. Also, the distributive channels through which confectionery of this type flows require that it have a fairly long shelf-life. For some products this requires larger amounts of corn sirup than would be needed if the product were consumed shortly after it was produced. Confectionery items sold by manufacturers who are also retailers ordinarily contain smaller amounts of corn sirup than similar items produced by manufacturers who sell through wholesale channels. This is possible because the price charged by the manufacturer-retailer ordinarily is somewhat higher and will permit higher ingredient costs and because the short time between manufacture and sale eliminates the need for properties conducive to a long shelf-life.

The amounts of corn sirup used by a manufacturer in many candy pieces often fluctuate as much as 5 to 10 percent with the season of the year. A smaller amount is used in summer because of the tendency which some candies have to sweat in hot weather if made with as large an amount of corn sirup in that season as in the wintertime. However, when the price differential is heavily in favor of corn sirup, a few firms lengthen the time for cooking a batch or raise the temperature to which it is cooked, rather than adjust the amount of corn sirup downward during the summer months.

The percentage of corn sirup in a formula usually associated by the trade with high-quality candy varies with the type of cooker used as well as with the type of candy and with the price differential between sugar and corn sirup. Most manufacturers prefer not more than 25 percent of corn sirup when using open-fire kettles, but think that 40 percent is allowable when using vacuum pans. When the latter method is used, larger amounts of a hygroscopic ingredient such as corn sirup can be used without affecting the physical characteristics of the batch because a greater amount of moisture may be removed from the batch without the danger of excessive caramelization. While confectioners use corn sirup in varying amounts in most types of confectionery items, this sweetener has a number of inherent characteristics which ordinarily limit its use to a certain proportion of total sweetener, and in many types encourage the use of high proportions of sugar. For example, the dextrins in corn sirup tend to make candy gluey or sticky if too much is used, resulting in sweating during hot weather and periods of high humidity. Using corn sirup exclusively also can adversely reduce the sweetness. In some types of confectionery it is desirable to maintain sweetness at a high level yet produce candy with physical characteristics not readily achieved when granulated sugar alone is used. These desired physical characteristics are largely those related to control of graining and moisture retention in the candy, the proper regulation of which governs the tenderness and aids in extending shelf-life. Fondants and cream centers offer the best illustrations of confectionery of this type.

Methods used to secure the desirable physical characteristics in these products include use of small amounts of invert sugar or corn sirup; use of an inverting agent, such as invertase; or use of a partially inverted type of liquid sugar. One of the primary advantages of using corn sirup in such cases is that it usually is the less expensive and appears to be of little disadvantage if used in relatively small amounts (10 to 15 percent). When some reduction in sweetness is also desired, corn sirup possesses an additional advantage. Because of their higher sweetening power and lower dextrin content, the high-conversion types of corn sirup can sometimes be used as a larger percentage of total sweetening ingredient than the regular type corn sirup before adverse effects upon quality are encountered. However, many confectioners believed that the advantages of high conversion sirup over regular sirup were not sufficient to offset their higher price and warrant their widespread use in confectionery. There does appear to be an increasing usage of the high conversion types when corn sirups are for the same purposes as invert sugar.

Sugar vs. Dextrose

Dextrose is used in either its hydrous or anhydrous form by about one-fifth of all the confectioners and chocolate manufacturers included in the survey. However, it usually comprises only a small percentage of total sweetener and in most cases the volume of dextrose used by the reporting company is negligible. An additional 40 percent of those interviewed reported using it during the war years, but said they discontinued its use after sugar became readily available again in late 1947. Although it was used by some in various types of confectionery, its use was more widespread in marshmallows, gums and jellies than in other types of candy. Use of dextrose by confectioners in 1948 ranged from one-eighth of the manufacturers in the West to slightly less than one-fourth in the Southern and Middle Atlantic States. (See Table19) Based on the 144 interviews made within this industry, it appears that dextrose is normally utilized in confectionery as a replacement for sugar rather than corn sirup. The fact that dextrose does not impart the same physical characteristics to candy as does corn sirup is, of course, the major deterrent to the replacement of corn sirup by dextrose. The amount of the replacement of sugar by dextrose varies with the type of candy being made, but usually ranges from 5 to 20 percent of total sweetener.

Confectioners who favored the use of some dextrose reported doing so for three principal reasons: (1) a belief that dextrose has properties which make for a creamier batch and extend shelf life of the candy; (2) because dextrose permits a reduction of sweetness which is considered desirable by some confectioners in certain types of candy; and (3) because dextrose sells at a price differential under sugar.

The group which used dextrose during the war and has since discontinued its use, and those who have never used it, objected to it on the grounds that: (1) due to its lesser degree of sweetness and solubility in comparison with sugar, it tends to make candy coarse-grained and

Table 19. Confectionery, all types: Corn sweetener usage by confectioners and chocolate manufacturers, by areas, United States, 1948

Type of Corn Sweetener Used	New England States		Middle Atlantic States		Southern States		North Central States		Western States		United States	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Regular Corn Sirup	11	84.6	27	90.0	28	96.5	43	86.0	14	87.5	123	89.1
High Conversion Corn Sirup 1/	3	23.1	4	13.3	5	17.2	8	16.0	3	18.8	23	16.7
Dextrose 2/	2	15.4	7	23.3	7	24.1	11	22.0	2	12.5	29	21.0
Any corn sweetener	13	100.0	27	90.0	29	100.0	46	92.0	14	87.5	129	93.5
Used no corn sweetener 3/	-	-	3	10.0	-	-	4	8.0	2	12.5	9	6.5
Total Manufacturers	13	100.0	30	100.0	29	100.0	50	100.0	16	100.0	138	100.0

Source: Marketing Research Surveys, Sugar Branch, PMA

1/ In the New England States--2 (15.4%), in the Southern States--1 (3.4%), and in the North Central States--3 (6.0%) of the manufacturers used only high-conversion corn sirup in combination with sugar.
2/ No manufacturers used only dextrose in combination with sugar--the corn sirups were used in at least one or more products by the corn sweetener users.
3/ Chocolate and licorice manufacturers only.

and sandy when used in high enough percentages to be an economic substitute for sugar; (2) when enough is used to net a saving over cost of sugar replaced, it may tend to make candy sticky, sweaty, and hard to handle in hot weather; (3) it may discolor and toughen candy which must be cooked to a higher temperature; (4) it occasionally crystallizes out in pumps and pipe lines.

Many declared that the price differential between sugar and dextrose was not a factor in deciding for or against the use of the latter. These manufacturers felt that by the time consideration was given to the increased amounts of dextrose required to compensate for its lower sweetening value, and costs for handling a third sweetener were figured, any advantage in price differential was eliminated. Confectioners also generally thought that dextrose was customarily priced too high in relation to corn sirup to be an economic substitute for it in a candy formula.

SWEETENER USE BY TYPE OF CONFECTIONERY

Hard Candies

Hard candies, as discussed herein, include not only those types which are easily recognized as "hard," but also such allied kinds as brittles, crunches, crisps, toffeys, hard mints, and mint drops. Granulated sugar is by far the more important of all sweeteners in hard candy manufacture, being used in higher ratios to other sweeteners than in any other class of confections except chocolate. Generally speaking, all of the sweeteners having predominant invert characteristics, such as partially inverted liquid sugar, invert sugar, honey, high-conversion corn sirup, and molasses, are not popular in hard-candy manufacture, due to their tendency to cause excessive sweating during humid weather. Turbinado sugars are rarely used in hard candies because they also tend to impart discoloration and an excessive molasses flavor.

A large proportion of high-quality hard candies was reported to be made with from 60 to 70 percent sugar, and the balance of total sweeteners being regular corn sirup. Almost one-third of the hard candy manufacturers visited were using 60 percent and 40 percent corn sirup while slightly more than a fourth reported using 70-30 proportions. When open-fire cooking methods were used, ratios of 70 percent sucrose to 30 percent corn sirup were common. In the more modern vacuum-pan cookers, a ratio of 60 percent sucrose to 40 percent corn sirup was very common. The majority opinion was that corn sirup in excess of 40 percent of total sweetener causes excessive sweating and stickiness of hard candies in hot or humid weather. It was not uncommon, however, to find hard candies of average and good quality being made with higher percentages of corn sirup, since 15 percent of the manufacturers reported common usage of a 50-50 formula. Individual pieces are often wrapped in moisture resistant cellophane, or the candy may be packaged in glass

containers; and more corn sirup may be used when the candy is to be marketed in cold weather.

A few firms reported using 100 percent sugar in hard candies, but in general, this percentage of sugar was reported to cause excessive graining or to make candies chalky. At the opposite extreme, confectioners occasionally made use of 100 percent corn sirup, and no sugar, in order to keep in business during the war rationing period, but stated that while it did make hard candy which could be marketed, it lacked sweetness, was difficult to handle in humid weather, and did not fracture properly in eating.

Under normal conditions only a few manufacturers were using high-conversion corn sirups or dextrose. Even during the war their use of these products was not widespread. The high dextrin content of regular conversion corn sirup is what is wanted in a corn sweetener for making hard candy. The high-conversion sirups and dextrose, moreover, are both more expensive than regular corn sirup. Although corn sirup solids were used during the rationing period in hard candy formulas, sometimes for up to 45 percent of total sweetener, they are not used now, because the desired characteristics can be imparted to hard candy at less cost by the use of regular corn sirup.

Fondants and Creams

The manufacturers of fondants and creams are treated here as a group. While fondants are sometimes sold as such, they usually form the basis for creams. Basically, fondant is made with either all sugar plus a small amount of invert sugar or inverting agent, or with sugar plus either regular corn sirup or a combination of regular and high-conversion corn sirups. The sweeteners are cooked to the proper temperature, cooled to creaming temperature, and then creamed to give the consistency known as fondant. In the manufacture of creams, the fondant base is further processed through the addition of what the industry knows as: (a) a "bob" (a sirup similar to that used for the fondant but not creamed); (b) a "frappe'" (consisting of corn sirup and sugar or invert sugar, and albumen, which have been boiled and beaten until similar to meringue or marshmallow); or (c) a "mazetta" (another of the marshmallow-like products, similar to a "frappe"). These intermediate products are worked up into various candies coming under the general heading of "creams."

From the surveys, it is apparent that the greater proportion of manufacturers of fondants and creams use a relatively high ratio of sugar in proportion to corn sweetener, which is usually regular corn sirup. The ratios used by about 40 percent of all fondant manufacturers and about half of the makers of creams interviewed ranged from 70 to 80 percent sugar to 20 to 30 percent corn sirup. The bulk of the remainder felt that fondants and creams of acceptable quality could be made with 60 to 65 percent sugar and 35 to 40 percent regular corn sirup. Although a few firms reported that the use of corn sweetener up to 50 percent or

more of total sweetener was resorted to in periods of shortage or to meet a lower quality demand, ordinarily the minimum proportion of sugar required to make acceptable creams and fondants was considered to be about 40 percent. If more than 40 percent corn sirup were to be used, it was thought that the product would be likely to be heavy and tough, and lacking in sweetness. Many confectioners making high and medium quality creams and fondants with percentages of corn sirup ranging from 20 to 40 percent of total sweetener, prefer to use invert sugar up to about 5 percent of total sweetener and decrease the proportion of corn sirup accordingly. When invert sugar is not used, all or a portion of the corn sirup may consist of the sweeter high-conversion type, the objective being to obtain a sweeter and more tender product than would result with the larger percentage of regular corn sirup.

In both creams and fondants it is not uncommon for confectioners to use 100 percent sugar, cooking this with a little inverting agent, such as cream of tartar, or tartaric acid. A very small amount of the enzyme invertase is often added, after cooling sufficiently and before coating with chocolate, to control graining, give longer shelf life, and prevent fermentation by making it possible to work the batch to a higher temperature or density. As the proportion of sweetener represented by sugar is decreased and corn sirup is increased, the need for the inverting agent diminishes. When the proportion of corn sirup is 30 percent or more, most confectioners do not use inverting agents in fondants and creams.

The proportion of sugar and corn sirup used in fondants and creams depend largely in the first instance upon the previously determined quality of product or type of market for which the product is intended.

Once a manufacturer has decided whether he wants to produce for the average or high-quality market, it is a matter of judgment as to the ratio of sugar to corn sirup which he believes best from a technical standpoint. If he has decided to aim for a high-quality fondant or cream, for example, the primary consideration in deciding whether to use as little as 10 percent or as high as 30 percent corn sirup is the question as to what combination will best yield a product having the desired characteristic.

The price of corn sirup in relation to sugar is also important, and this consideration becomes increasingly important as the price competition among manufacturers narrows the margin between selling price and production costs. The price differential appeared to be more important to firms using regular corn sirup as the sole other sweetener in combination with sugar. Where manufacturers were using high-conversion corn sirup as all or part of the total sweetener, or were using some invert sugar along with the corn sirup, the price differential between sugar and corn sirup did not appear to be as significant a factor. Instead, the choice of sweeteners, in these cases, seemed

to depend largely upon preferences associated with the differences in physical properties imparted to fondants and creams by the use of various proportions of these sweeteners.

Nougats and Caramels

Most manufacturers of nougats and caramels were using from 50 to 60 percent sugar, and the balance corn sweeteners. By far the most commonly used corn sweetener was regular corn sirup. High-quality nougats and caramels were made by using approximately 60 percent sugar, while those with 50-50 ratios were considered to be of about average quality. About half the caramel manufacturers and about a third of those making nougats were using half sugar and half corn sirup, while about a fourth of the caramel manufacturers and a third of the nougat manufacturers stated that they used 60 percent sugar and the remainder corn sirup. Extremely high-quality nougats and caramels were sometimes made with as high a proportion as 70 percent sugar, but this was said to represent about the maximum sugar usage consistent with maintenance of the desired chewey characteristics of these types of candy. Sugar in excess of 60 percent was reported to cause graining in nougats and caramels, unless accompanied by low percentages of invert sugar, or unless an inverted type liquid sugar or high-conversion corn sirup is used. On the other hand, average quality caramels reportedly are possible with as little as 30 percent sugar, if the remaining 70 percent is made up of high-conversion corn sirup. Similarly, a combination of 60 percent regular corn sirup, 5 percent invert sugar and 35 percent sugar was said to be suitable for producing average quality caramels.

Despite the statements of confectioners that high-conversion corn sirups and invert sugar could advantageously be used in place of a part of the regular corn sirups, in order to make caramels and nougats sweeter and more tender, only a small proportion of them were using these products, presumably because of the additional cost incurred unless the proportion of sugar is simultaneously lowered.

There appeared to be considerable evidence that manufacturers of nougats and caramels varied the proportions of sugar and corn sirup to take advantage of changes in the price differential between these two sweeteners. Most of this variation seemed to occur between the two ratios of 60 percent sugar to 40 percent corn sirup and 40 percent sugar to 60 percent corn sirup. As confectioners approached the latter ratio, however, they usually made use of small percentages of invert sugar or shifted, at least in part, to high-conversion corn sirup, in order to counterbalance the toughening and loss of sweetening which would result if only sugar and regular corn sirup were used in a 40-60 ratio.

None of the surveyed firms making caramels reported the use of dextrose, and only 10 percent of the producers of nougats reported its use at that time. Use of dextrose in nougats was in very small proportion of total sweetener--usually not more than 5 or 10 percent. During

the war years, however, it was used frequently up to 50 percent of total sweetener. One reason given for not liking dextrose was that it toughened the candy. Those who used some dextrose in making nougats believed that it could be substituted for a certain amount of sugar at a slightly lower cost than by use of corn sirup alone with sugar. On the other hand, there were many who saw no particular financial advantage in using small percentages of dextrose, and expressed a dislike for handling a third sweetener.

During the war, corn sirup solids were used in making caramels and nougats in amounts up to 20 percent of total sweetener. Use of this product has now been practically abandoned, however, because its hygroscopicity in small lots in an open bag makes it hard to handle, and because it costs more than corn sirup. The survey showed candy manufacturers can use direct-consumption types of sugar to advantage in nougats and caramels because of the darker color of these candies. Their use up to 40 percent of total sweetener was reported by a few companies, such use being attributable, of course, to the price differential under fully refined sugars. Honey and molasses were popular in these two confections as flavoring agents.

Gums and Jellies

Some combination of sugar and regular corn sirup is by far the general rule in making gums and jellies. Of the 51 plants surveyed which produce these types of confections, all used sugar and all but four used regular corn sirup. Only one plant used invert sugar, while the percentages of those using dextrose and high-conversion corn sirup were 15.7 and 7.8, respectively.

The consensus among manufacturers was that top quality is achieved when two-thirds of the sweetener is sugar and the remainder is regular corn sirup. Average quality gums and jellies were said to result with 50 to 60 percent corn sirup, or even as much as 70 percent corn sirup, if the pieces are sanded or coated. Sanding the piece with coating sugar reduces the tendency to sweat in hot and humid weather when high percentages of corn sirup have been used. Almost half of those who were making gums and jellies used half corn sirup and half sugar for the sweetener contents, while another 20 percent preferred to use 60 percent corn sirup. Toughness and sweating were reported to result if the proportion of corn sirup was more than 60 percent. Confectioners indicated that temperature of the cook was as much a controlling factor for producing tenderness or toughness in gums and jellies as is the percentage of sugar and corn sweetener used. During the World War II sugar shortage, confectioners frequently used corn sirup as the only sweetener in these products.

As with nougats and caramels, the price differential between sugar and corn sirup materially affects the proportion of these two sweeteners used in gums and jellies. An increase in the differential will encourage those using a 60-40 ratio to switch to a 50-50 or even a 40-60 formula,

and a narrowing of the differential will have the opposite effect. Other considerations usually restrict a confectioner from adjusting the proportion of sweeteners beyond this 20 point range.

High-conversion corn sirups appeared to be gaining in popularity for this type of product, offering greater sweetness than regular corn sirup, and a more tender piece. It was reported that sugar percentages could be reduced considerably when the high-conversion type was substituted for regular conversion corn sirups. Some manufacturers indicated that production costs could be lowered when high-conversion sirups were used for replacing part of the sugar and part or all of the regular corn sirup requirements. Many felt that use of this sweetener and less sugar increased the shelf life and gave the products the desired degree of sweetness, and that its use instead of regular corn sirup improved texture and flavor.

Considerable controversy was found to exist as to the place of dextrose in making gums and jellies. Those who did not favor its use maintained that batches containing it must be cooked to a higher temperature, with resultant toughening and discoloration attributed to caramelization of the dextrose. Others, however, maintained that dextrose in amounts up to 25 percent of total sweetener aided in moisture retention in these pieces, made them more tender, and allowed a little reduction in ingredient costs.

Marshmallows

The most common sweetener ratio used by the marshmallow manufacturers interviewed approximated half sugar and half corn sirup. This is the point where they reported that the amount of sugar needed for this type of candy is being provided and maximum savings in cost of materials are attained. When the proportion of corn sirup is increased beyond 50 percent, marshmallows were said to have a tendency to become sticky and lack sufficient body to hold up firmly. However, some firms used as high as 85 percent corn sirup and said they were making a marshmallow which was quite acceptable in certain markets. Several confectioners reported making marshmallows with 100 percent corn sirup during World War II; these products were admittedly tough and had a short shelf life, but, when coated, were acceptable under wartime conditions. The minimum amount of corn sirup used in marshmallows was reported to be 40 percent of total sweetener. Using less than this amount was reported to result in too dry and stiff a marshmallow. Proportions of sugar and corn sweeteners are rather flexible in this type of confection, and a high-quality product can be produced using a wider variety of sugar-corn sweetener ratios than is generally true of other confections.

Regular corn sirup was by far the most common corn sweetener used in making marshmallows, being employed by about three-fourths of the producers. About one-fourth of the 29 manufacturers used high-conversion corn sirup, about a fifth used dextrose; and most of them used regular corn sirup as well. Use of invert sugar was rarely reported, since

other sweeteners, principally high-conversion corn sirup, were said to do a similar job of controlling grainings, increasing tenderness, improving keeping quality and at a lower cost.

High-conversion corn sirups are steadily gaining in favor among marshmallow manufacturers because, being sweeter, they help to reduce costs of production by replacing a greater amount of sugar than is possible with regular corn sirups. In addition, these sirups were said to have the property of keeping marshmallows from drying out when their shelf life would be likely to be long, and their lower dextrin content was said to give a marshmallow with a more tender or "fluffy" texture.

Several confectioners indicated that dextrose could readily be used for replacement of from 10 to 20 percent of the sugar content. They thought that this amount of dextrose gave more body to the marshmallow, improved its texture, and increased its moisture-retaining properties, and that this practice permitted a small saving in material costs. On the other hand, many manufacturers indicated the belief that beneficial results or economies derived from the addition of dextrose were insufficient to warrant the trouble and expense of handling a third sweetener.

In the manufacture of marshmallows the use of larger amounts of corn sweetener has persisted since the war emergency, when it was the general practice of many confectioners to use as much of these sweeteners as possible. In many instances less sugar and higher ratios of the high-conversion corn sirups, plus enough dextrose to stiffen and improve the texture of the marshmallows, were being used at the time of this survey.

Fudge

Sweeteners used in the great bulk of fudge manufactured for general use usually consist of between 60 to 70 percent sugar and 30 to 40 percent corn sweeteners, with or without the use of small percentages of invert sugar. The best ratio for all-around use was reported to be 70 percent sugar and 30 percent regular corn sirup, this being just enough corn sirup to maintain the proper softness of the piece, control crystallization, and prevent grainy consistency. Some manufacturers use regular corn sirup while others use a combination of the regular and high-conversion types. Some invert sugar is often used instead of high-conversion corn sirup. Manufacturers indicated, however, that invert sugar cannot be substituted for all of the corn sirup ratio called for, because of the need for the dextrins of corn sirup to control body and texture of the piece and reduce the sweetness.

Although fudge made with as much corn sirup as 40 percent of total sweetener was disliked by some because they believed the flavor of corn sirup too detectable at this point, this combination was fairly popular because materials cost in acceptable quality fudges was minimized at

this point. In wartime, the sugar content dropped below 60 percent but high-conversion corn sirups or invert sugar were added to bring up the sweetness and to tenderize the product. Proportions of sugar above 70 percent were generally considered too expensive for profitable operation. However, many high-quality fudges are made with 75 or 80 percent sugar, around 5 percent high-conversion corn sirup or invert sugar, and the remainder regular corn sirup. Proportions of sugar in excess of 80 percent of total sweetener were considered to result in fudge which was too dry or short. Therefore, the area of substitution between sugar and corn sirup in making fudge is largely in the area between 60 and 80 percent sugar. It is only within this 20-point range that changes in the price differential between sugar and corn sirup have any material effect upon the proportions of sweeteners used. However, price relationships between regular and high-conversion corn sirup and between these sirups and invert sugar determine to a large extent the exact proportions of those sweeteners which will constitute the 20 to 40 percent of total sweetener which is not sugar.

Sixty-five percent of the fudge manufacturers reported using dextrose at the time of the survey. Ordinarily it was not used in amounts in excess of 10 to 15 percent of total sweetener. Manufacturers who favored its use felt that small amounts of this sweetener resulted in a fudge which was tender and had good moisture-retaining properties. If used in excess of 10 to 15 percent, however, dextrose was said to cause excessive crystallization. The price differential between sugar and dextrose seemed to encourage little use of dextrose in fudge. On the other hand, the lower price of corn sirups and the cost and inconvenience of handling another sweetener definitely seemed to discourage the use of dextrose.

Chocolate

The sweetener content of chocolate depends to a large degree upon the type of chocolate being made. However, there may be considerable variation in sweetener content within a given type, since the type of chocolate depends more upon the proportions of cocoa, milk and butter used than upon the sweetener content. The four rather distinct types of chocolate recognized in the trade are sweet, milk, semi-sweet, and bittersweet. The sweetener content of sweet chocolate was reported to vary from 38 to 50 percent; semi-sweet from 30 to 45 percent, and milk from 20 to 53 percent. Bitter-sweet ordinarily contains very little sweetener, but in some cases was reported to be made with from 7 to 20 percent.

Manufacture of chocolate is one industry in which there is little use of any sweetener other than granulated sugar. Except for the use of corn sirup in making chocolate sirups for soda fountain and home use, the 14 chocolate manufacturers surveyed reported using no corn sweetener at the present time. However, about two-thirds of these plants did use

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dextrose during the war. Direct-consumption type sugars were being used by only two of the fourteen manufacturers; during the war these sugars were used by two other plants.

Only dry sweeteners such as sugar, anhydrous dextrose, (or corn sirup solids) are permitted by Federal food standards in the manufacture of sweet chocolate or sweet chocolate coatings. Generally any sirup was strongly objected to, because of the difficulties of coping with excess moisture. However, a few chocolate manufacturers who use fluid milk in making milk chocolate did not object to the use of liquid sugar, since it can be mixed with the fluid milk and then dehydrated prior to combining with the chocolate liquor. In the manufacture of the other types of chocolate, semi-sweet, bitter-sweet, milk, and sirup, there are no Food and Drug Administration restrictions on the type or amounts of sweetener, dry or liquid, that may be used.

Dextrose was more popular than corn sirup solids in chocolate products during periods of sugar shortages, primarily because of its greater sweetening power, less hygroscopic property, and ease of handling. Dextrose was most commonly used in milk chocolate. Although Federal food and drug regulations permit use of dextrose in sweet chocolate up to a third of total sweetener, and place no limit in its use in other types of chocolate, it ordinarily was not used in amounts greater than 25 percent. When it was used in greater proportions, a product which lacked adequate sweetness was reported to result.

Chewing Gum

Sweeteners account for 70 to 80 percent of the total weight of chewing gum. Of the total amount of sweeteners used in chewing gum, from 60 to 75 percent usually is regular corn sirup, the remainder being sugar or a combination of sugar and dextrose. Corn sirup solids, invert sugar, and high-conversion corn sirups normally are not used.

Sugar is needed in chewing gum to provide the desired sweetness, whereas corn sirup is essential for the provision of chewey characteristics supplied by the dextrins in combination with the gum base. Unlike many types of confections, high-quality chewing gum is not necessarily associated directly with high sugar proportions. Some low-quality gums were reportedly made with 50 percent sugar, while 40 percent or less sugar was quite common in many high-quality types. This would appear to indicate that the price differential between sugar and corn sirup was a relatively unimportant influence affecting proportions of these sweeteners. The desired sweetness and degree of chewiness appear to be the primary considerations influencing the combination selected.

The primary area of competition between sweeteners in making chewing gum is between granulated sugar and dextrose. The price differential between these two encourages many manufacturers to use dextrose up to the limit permitted by its physical characteristics. Those who do not use dextrose fail to do so principally because of the mechanical

disadvantages associated with using three different sweeteners (sugar, corn sirup, and dextrose). While some firms making bubble gum ran up the percentage of dextrose to total sweetener as high as 24 percent, the general average in high-quality chewing gum ranged between 5 to 10 percent. Manufacturers reported many difficulties when trying to use dextrose in excess of 10 percent. For example, it was necessary for them to adjust air-conditioning temperatures in the whole plant when larger amounts of dextrose were in the mix. In other instances the dextrose crystallized out and interfered with the mechanism of the chewing gum production line. Normally, it is the dissolved sugar which lubricates all of the surfaces in the chewing gum production line to prevent the batch from sticking anywhere during the manufacturing process. When dextrose in excess of 10 percent was used, its slower rate of entering into solution, in relation to sugar, caused it to crystallize and make the batch adhere to the equipment. Some firms tried dextrose in the sugar coatings of chewing gum but found that it did not adequately prevent stickiness during hot weather.

THE CANNING INDUSTRY

The Purpose of Sweeteners in Canned Foods

Almost all fruits, the majority of acid vegetables, and some of the non-acid vegetables are canned with a sweetening agent or agents. The use of sweeteners in canned foods is primarily to improve the flavor or palatability of the product, preserve natural colors, and prevent material changes in the texture of their cellular structure. The use of what is known as a "canner's" grade of sugar, which has been treated by ultraviolet rays or other suitable process to reduce the count of thermophilic bacteria sometimes present, is a precaution taken in the canning of non-acid foods, especially vegetables. Protection from fermentation and growth of bacteria or molds in canned foods is controlled principally through heat processing and packing in air-tight containers.

Fruits which are intended to be eaten directly in the form in which they come from the can are better dessert items when sweetened. Those which are to be used in jelly-making, pie fillings, or salads, may be unsweetened, since they are sweetened or seasoned to taste when used.

In canning, the fruit is subjected to temperatures sufficiently high to kill all actively-growing bacteria and yeasts. The sirup which is then added may be made with the sweetener or sweeteners of the canner's choice so long as their use is permitted by applicable Federal and State food standards governing the particular fruit being canned. Mandatory Food and Drug Administration regulations or voluntary U.S.D.A. standards, and in isolated cases, State laws place limitations on the use of sweeteners in certain canned foods. These limitations may be with respect to the type of sweetener permitted, the proportion of total sweetener which may be comprised of a particular sweetening agent, ranges in the amounts of sweeteners which must be used, or requirements for labeling identification. (See pages 80 to 94 for detailed discussion of the impact of Food and Drug regulations, U.S.D.A. standards, and selected state laws on sweetener usage.)

Amounts of Sweeteners Used in Canned Foods

The amount of total sweetener with which fruits are canned is related to the density of the sirup added to the fruit. This density is usually expressed in terms of degrees Brix, which is the approximate percentage of solids in the sirup. Low-density sirups, familiarily known as "light" sirups, are usually 20° Brix or less, while high-density sirups, called "heavy" or "extra-heavy" are often 60° Brix or more. Medium-density sirups have an intermediate Brix reading.

When sugar is the sole sweetening agent and only water is used to make the sirup, the weight per gallon of a 20° Brix sirup at 20°C would be 9.012 pounds, while that for a 60° Brix sirup would be 10.727 pounds

at the same temperature. 63/ Thus, a gallon of 20° Brix sirup would contain 1.802 pounds of sugar (20 percent of 9.012) while the same quantity of 60° Brix sirup would contain 6.436 pounds, or more than 3 times as much. This shows that there is not a 1 to 1 relationship between variations in Brix and sugar content per gallon. Because some of the corn sweeteners are not moisture-free, larger amounts of these must be used to produce sirups of equivalent density.

The density of the packing sirup becomes considerably thinned in canning as the result of an interchange of a part of the sirup with the lighter-density natural juices of the fruits. This interchange is complete and the Brix becomes constant approximately 15 days after canning. The sirup density then prevailing in the pack is known as "cut-out" Brix and may be as low as 12° to 14° for the light sirups, the original density of which was 20°, and from 24° to 30° for the heavy sirups of original densities from 50° to 60°. The specifications for sirup densities included in food standards are usually in terms of "cut-out" Brix. There is no hard-and-fast relationship between "put-in" Brix and "cut-out" Brix. The relationship varies with type and grade of fruit, density of sirup, and proportion of sirup used.

The density of sirup in which fruit is packed varies with the type of fruit and differences in the quality of grade. Fruits which are bland or delicate in flavor may be packed in the lighter sirups to avoid masking their flavors by excessive sweetness. Some canners prefer to prevent excessive sweetness in fruits packed with relatively heavy density sirup by using one of the corn sweeteners as a portion of the sweetening ingredient. With fruits which are highly acid or which have rather strong or pronounced flavors, the heavier (sweeter) sirups may be used without too much concern over their effect on the fruits' natural flavors.

Table 20 gives the range in sirup densities and the densities most frequently used which have been reported for the principal canned fruits and fruit juices.

While vegetables are not necessarily canned with the use of a sweetener, a few of them, principally beans, peas, and corn, and various sauces such as chili sauce, catsup, etc. are put up with small amounts of sweetener added as a seasoning, like salt or spice, to accentuate or improve their natural flavors. In the case of these products, the Federal food and drug standards limit the sweetener which may be used to sugar and dextrose. The amounts used vary considerably for the different products, and for the same product they differ according to the preferences of individual canners. Food standards ordinarily do not specify any minimum or maximum amount of sweetener for use in canning vegetables. The amounts reported for certain vegetables are given in Table 21.

63/ Spencer, Guilford L. and Meade, George P., A Handbook for Cane Sugar Manufacturers and Their Chemists. N.Y., John Wiley and Sons, 7th Edition, 1929, Table 33A, pp. 476-7.

Table 20 - Densities of Packing Sirups when Sweeteners are Used in Canning Berries, Fruits and Fruit Juices

Berry, fruit, or fruit juice	Range in density		Most usual density
	Low	High	
	° "Put-in" Brix	° "Put-in Brix	° "Put-in" Brix
Apricots	60	67	65
Cherries	40	67	50
Citrus juice	12	14	12-13
Citrus segments	14	18	16-18
Fruit cocktail	40	50	45
Peaches	50	67	67
Pears	20	67	45

Table 21 - Amounts of Sweeteners Often Used in Certain Canned Vegetables and Related Products

Product	Sweetener Range		Average Amount of Sweetener Used
	Low	High	
Percent of Sweetener to Total Weight of Finished Product:			
Beans, kidney	1	1½	1
Beans, lima	1	1½	1
Pork and beans	½	4	1½
Peas, garden	½	1½	1
Soups	1	4	2
Catsup	7	26	17
Percent of Sweetener in Brine or Sauce:			
Beans, Boston-baked	5	19	13
Beans, green	1	4	3
Beans, kidney	2	17	8
Pork and beans	10	18	14
Peas, garden	3	7	4
Corn, sweet	4	15	7

Use of Sugar in Canned Foods

Number of Canners Using Sugar - Sugar and dextrose are the sweeteners most commonly used in canned foods. Other sweeteners include sirups or corn sirup solids, molasses, and honey. All canners surveyed used sugar in either granular or liquid form, and no particular preference was indicated for either cane or beet sugar. Approximately 64 percent of the canners who were contacted reported that they used sugar as the sole sweetening agent.

Although about 90 percent of the canners said that they used only dry sugar, liquid sugar was found to be increasing in popularity. Many canners claimed that liquid sugar containing a substantial proportion of invert sugar was more effective than dry sugar in tenderizing the skins and conserving the fruit's natural texture. On the other hand, many believed that the additional water in liquid sugar (or, for that matter, additional water added to the product by any sweetener in sirup form) was a handicap, in that it diluted the natural fruit juices excessively.

A small number of canners reported the occasional use of direct-consumption sugars. These were used solely for economy and principally in the Chicago area and the South, where competition is keener and some of the smaller firms found it necessary to pare their production costs. In products such as pork and beans or sweet potatoes, the slight molasses flavor of turbinados was said to be unobjectionable. Molasses and honey were used for flavoring as well as sweetening agents for such products as Boston baked beans, red kidney beans, and tinned, dark breads.

Reasons for Use of All-Sugar Packs - The survey showed that long association of sugar with high-quality canned goods is a major factor influencing many canners to retain their well-established all-sugar packs rather than experiment with other sweeteners. Since canned goods are bought largely on the basis of brand names, many of the larger and more widely-known firms are reluctant to change their formulas for fear of upsetting established consumer preferences. There are canners, of course, who believe that any change from an all-sugar formula actually would result in a lowering of quality, and that economies, if any, resulting from use of corn sweeteners in any amounts would be more than offset by a lowering of consumer acceptance for the product. Another advantage of using all sugar in packs, as reported by the canners interviewed, was that it was the only sweetener which could be used alone in a broad variety of items. Handling two or more sweeteners was said to add to in-plant handling expenses and to increase the chances for error in the formulas. The principal disadvantage of some all-sugar packs were said to be excessive sweetness and a masking of delicate fruit flavors.

Use of Dextrose in Canned Fruits and Vegetables

Number of Canners Using Dextrose - About a third of all the canners interviewed used dextrose. Dextrose was found to be most popular among the canners on the West Coast and in the Florida citrus area, where in

approximately half of the plants visited, canners were using it. Nearly half of the canners used dextrose at times during the recent war. Its current acceptance is due in part to the wartime experiences.

Proportion of Total Sweetener Composed of Dextrose - In most instances, dextrose was being used in combination with sugar. As a general rule, dextrose comprised from 20 to 25 percent of the total sweetening ingredients when used in canned fruits and vegetables. The most usual proportions for dextrose are given in Table 22. It will be noted that, while Federal food and drug standards for certain canned fruits (peaches, apricots, pears, cherries, and fruit cocktail) allow dextrose to be used up to one-third of total sweetener, canners usually preferred to hold the proportion of this sweetener to 20 percent. Such a limitation on the use of dextrose reportedly was for the purpose of preventing carmelization when high cooking temperatures were used and avoiding crystallization during cold weather and refrigeration. The highest percentages of sweetener comprised of dextrose were found to be used by the canners of citrus segments and juices. Many citrus canners were using half dextrose and half sugar, while a few reported using 100% dextrose. The flavor of most canned citrus products is characteristically bland. Use of dextrose as a fairly large proportion of total sweetener is believed by many citrus canners to detract less from the natural fruit flavors. This viewpoint was commonly expressed in both California and Florida.

Table 22 - Most Usual Percentages of Total Sweetener Reportedly Composed of Dextrose

Fruits and Berries	Percent	Vegetables and Other Items	Percent
Peaches	20	Corn	25
Plums	20	Sweet Potatoes	25
Pears	20	Peas	25
Apricots	20	Succotash	15
Cherries	20	Beets	20
Fruit Cocktail	20	Beans and Tomato Sauce	20
Raspberries	25	Green Beans	15
Citrus Segments	50	Pork and Beans	25
Citrus Juice	50	Catsup and Chili Sauce	25
		Spaghetti Sauce	20

Advantages and Disadvantages of Using Dextrose

The majority of canners using dextrose stated that whenever not more than 20 to 25 percent of total sweetener was dextrose, there were no significant differences in color, texture, or flavor of the canned product, as compared with an all-sugar formula. The principal characteristic of dextrose which makes it popular with canners was said to be its ability to maintain the desired percentage of solids in the sirup, while at the same time effecting a reduction in total sweetness that enhances the natural flavors of some canned products. This was reported to be especially true in the case of fruits having a delicate flavor.

The greater osmotic pressure of dextrose solutions, in comparison with sugar solution of equal density or concentration, permits a more rapid entrance of this sweetener into the pores of the fruit. This more rapid exchange of sweetener for the natural juice of the fruit was said to aid in preserving good color and texture. Opinion was about equally divided with respect to the net effect on costs resulting from use of dextrose as a portion of the sweetening agent. Some canners believed that the price differential under sugar permitted a reduction, others maintained that because it was necessary to use larger amounts of dextrose to compensate for its lesser degree of sweetness, and because of additional in-plant costs of handling two sweeteners, costs were not materially lowered and might even be higher. Those who reported that the use of dextrose as a portion of total sweetener enabled them to reduce costs ordinarily were those who substituted dextrose for sugar pound for pound rather than using sufficient additional dextrose to compensate fully for its lower sweetening value.

A few canners objected to dextrose because they believed Federal food and drug standards required that it be declared on the labels of canned fruits and vegetables. (Such label declaration is not required.) Others claimed to see no cost-saving possibilities in using dextrose or did not want to be required to handle two sweeteners.

Some canners mentioned adverse reactions which they believed resulted from use of dextrose. Principal reasons given were that it lacked the desired degree of sweetness, it imparted a bitter flavor to the product, it caramelized at high-cooking temperatures, and crystallized when the finished product was refrigerated or subjected to cold weather. Most exponents of dextrose argued that the foregoing results are likely to be obtained only if dextrose is used as too large a percentage of total sweetener. They maintained further that such results are minimized or non-existent when dextrose is used in amounts usually recommended by food technologists and dextrose manufacturers.

The surveys disclosed that canners were in disagreement over the effect which dextrose has on the pigments in canned fruit. Some believed that it had a tendency to darken natural colors, particularly the red pigments, while others felt that it did just the opposite. For instance,

a few canners who used all dextrose in sweetening grapefruit segments believed that it aided in holding the whiteness of this fruit for a longer period of shelf life than all sugar, while approximately an equal number felt that 100 percent dextrose darkened the grapefruit.

Use of Corn Sirup in Canned Goods

Proportion of Canners Using Corn Sirup - Canners make relatively little use of corn sirups in their products. Food and Drug Administration standards do not permit the use of corn sirups or corn sirup solids in processing the canned vegetables to which present regulations apply. In canning fruit, corn sirups were reported being used as a portion of the sweetening ingredients in relatively few cases. Others reported their use only during the war rationing period.

Advantages and Disadvantages of Using Corn Sirup - Federal food and drug regulations stipulate that corn sirup may be used in canned fruits only in combination with sugar, or with sugar and dextrose, and restrict the proportion of corn sirup to not more than 25 percent of total sweetener. The Federal regulations also prohibit the use of corn sirup in canned fruits when fruit juice is the only liquid ingredient. When used in combination with sugar and in proportions not exceeding 20 to 25 percent of total sweetener, corn sirups were reported to have advantages similar and equal to dextrose in bringing out natural flavors through reduction of sweetness and maintenance of the desired texture or color of the fruits.

Some canners had the same objections to corn sirup that other food processors expressed, namely, its lack of sweetness in comparison with sugar and its tendency to impart an off-flavor to canned products when it is used in more than relatively small amounts. However, others who had experimented or were currently using the high-conversion type of corn sirups did not believe such objection to be valid. In smaller operations for which a distribution system for circulating sirups throughout the plant had not been provided, the in-plant handling difficulties accompanying the use of corn sirup delivered in drums were reported to be a major barrier to its use.

Commercial use of packs put up in 100 percent high-conversion corn sirups is prohibited by Federal Food and Drug regulations. However, a few plants in the fruit-producing areas of California indicated that experimental packs canned in 100 percent high-conversion corn sirup retained a natural fruit flavor superior to that of packs made with all sugar, sugar combined with dextrose, or sugar combined with corn sirup. Canners who made these experimental packs felt that this was especially convincing in the case of fruits processing delicate and more readily changeable flavors, such as pears.

THE PRESERVING INDUSTRY

Purpose of Sweetener in Preserved Items - Preservers' items discussed in this section include jams, jellies, preserves, marmalades, fruit spreads and fruit butters. In the manufacture of all these products it is necessary to use sweeteners for control of flavor, texture, fermentation and specific gravity. The preserving process is essentially one of forcing sugar into the fruit and water out of it. 64/ In this process, the inversion of some of the sugar, which is a natural result of heating the sucrose in the presence of fruit acids is important for the prevention of crystallization. Growth of bacteria and yeast is inhibited in a medium where the sugar concentration is above 65%; therefore, if the sugar content inside the fruit is raised to that point or above, the preserved product will keep indefinitely without spoiling or fermenting.

Sweeteners are used in preserves not only to prevent fermentation and spoilage, but also to equalize the specific gravity of the fruit and the liquid medium surrounding the fruit, so that an even distribution within the preserves will result. If, for example, a 68% sugar solution which has a specific gravity of around 1.3 is processed with fruit containing a natural fruit juice of a specific gravity of around 1.1, penetration of sugar into the fruit is essential in order to equalize the specific gravity and prevent the fruit from clustering at the tops of the containers. Sucrose solutions having a solids content of around 65% are stable at room temperature, but, when opened for consumption, surface evaporation frequently raises the sugar concentration sufficiently above 65%, to cause crystallization of the sugar. Some inversion of the sucrose is desirable to prevent crystallization in the product. Moreover, sugar sirup which has been partly inverted has a greater osmotic pressure and tends to enter the pores of the fruit more readily.

Use of Sweeteners in "Pure" Preserved Products - When jams, jellies, preserves or fruit butters are made to comply with Federal food and drug standards relating thereto they are referred to in the industry as "pure" products in contrast to those known as "imitation" products wherein the quality of fruit, proportion of sweeteners used and other factors do not necessarily conform with the Federal food standards. Pure jams, jellies and preserves, as well as marmalades, fruit butters, and fruit spreads are combined for discussion in this report under the heading of "pure" products. A brief separate discussion follows covering the role of sweeteners in making imitation jams, jellies and preserves.

Amounts of Sweeteners Used in Pure Products - Federal food and drug regulations specify that the amount of sweetener used in pure jams, jellies,

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64/ Meschter, E. C. Jam and Jelly Making, in Food Industries, June 1949 p. 67.

and preserves cannot exceed 55 parts of sweetener to 45 parts of fruit. Approximately 94% of the preservers, contacted, reported using the maximum amount of sweetener permitted by the Federal regulations. A relatively small percentage of the group reported normal use of a 50-50 sugar-fruit ratio because they considered these proportions resulted in extra high quality products most nearly resembling homemade items. Marmalades are not at present included under Federal food and drug regulations. The usual combination of sweetener and fruit for marmalades was said to be 65% sweetener and 35% fruit. The relationship between the price of fruit and price of sugar plays an important part in determining the amounts of total sweetener used. For example, when fruit is cheap the minimum requirement of 45% fruit may be increased to 50 or even to 60 percent in the case of certain fruits. On the other hand, as the price of fruit advances in relation to the price of sugar, manufacturers will tend to cling to the maximum amount of sweetener in relation to fruit permitted under law.

Types of Sweeteners Used in Pure Products - Competition between sweeteners in producing pure jams, jellies, and preserves consists essentially of choosing the optional sweetening ingredient, or combination of them permitted under Federal or State law, which will replace water in the fruits being preserved at the least cost commensurate with the desired quality and type of market for which the product is destined. State requirements usually follow Federal food requirements fairly closely with respect to type of sweetener permitted. The latter permit use of sugar, and either dextrose or corn sirup in combination with sugar, or cominations of sugar, dextrose and corn sirup. There is no limitation on the percentage of dextrose which may be used, except that it be used "in combination with sugar." However, use of corn sirup is limited to not more than half of total sweetener. Label identifications of all sweeteners are required when corn sirup is used. Corn sirup solids are not permitted in pure fruit preserves, jams and jellies. 65/

Use of Sugar as the Sole Sweetener in Pure Preserved Items - Insofar as preferences in the use of sweetener are concerned, preservers are divided into two groups: In one group are those who believe that quality preserved items can best be made with 100% sugar; in the other are those who believe just as firmly that the addition of dextrose or corn sirup up to a quarter or a third of total sweetener requirement produces a product equal to that made with all sugar. Nearly 70% of all preservers interviewed throughout the country in connection with this study belonged to the former group. The reasons given in favor of the exclusive use of sugar were based on the belief that this makes high quality preserves. According to this group, preserves of a better texture, with flavors and colors that are more natural, can be produced when 100% sugar is used.

65/ See above, pp. 80 to 94 for full discussion of the impact of Federal and State regulations on use of sweeteners in preserved products.

They also stated that less trouble is encountered with crystallization or stickiness. Several firms stated that their use of sugar as the exclusive sweetener was based on long established customs. Such practice was also attributed to lack of facilities for experimentation with other sweeteners. A considerable number, particularly the larger plants, also indicated a preference for the use of sugar only believing that the possibility of errors in handling materials in the plant would thus be reduced. Furthermore, the all-sugar group pointed out that storage and handling costs would be increased if more than one sweetener was used in their formulas.

Preservers ordinarily use highly refined sugar. However, a few reported the use of direct-consumption raw types in the darker colored products. The Food and Drug Administration has not specifically ruled against the use of these types, so long as they reasonably approach the standard of quality of refined sugar. In areas where it was available, beet sugar was quite popular among preservers. Approximately one-third of the preservers interviewed in the West and North Central regions were using no cane sugar. The chief reason given for the use of beet sugar was the price differential. The greater availability of cane sugar in the specialty grades is not important apparently in influencing a preserver's choice of sugar, because he needs relatively few grades. (See chapter on confectionery).

Liquid sugar is not very popular among preservers as only 8% of the firms interviewed reported using it. The lack of popularity of this product is due to its water content, since there is difficulty in evaporating excess water without over-cooking or discoloring the fruits. No firms using open kettle types of cookers had found liquid sugar suitable. The few manufacturers who used liquid sugar stated they liked it chiefly because of the convenience it offered as a medium for supplying the desired degree of inversion. Generally, liquid sugar was utilized only in connection with jams or jellies, where the further maceration of fruits, resulting from extension of cooking time or higher temperatures, was not a problem or where vacuum pan cookers were in use.

Invert sugar also was not popular with preservers who stated that on a dry basis invert sugar was more expensive than either sucrose or the corn sweeteners. They felt that the desired amount of inversion was usually obtained effectively during the cooking process at relatively little expense by adding an inverting agent.

Combination of Sugar and Corn Sweeteners in Making Preserves - Almost one-third of the preservers surveyed throughout the country reported favoring the use of corn sweeteners in combination with sugar. This group maintained that from a quarter to a third of the total sweetener could consist of one of the corn sweeteners, not only without altering the quality of jams, jellies, preserves, marmalades and fruit butters, but in some instances to improve flavor, color, and palatability.

Combination of Sugar and Dextrose - In 1948, dextrose was used either in combination with sugar alone or with both sugar and corn sirup by nearly one fourth of all preservers interviewed. An additional one third

reported the use of dextrose during the war, but these reverted to 100 percent sugar by the time of this survey.

Manufacturers using dextrose in preservers' items never reported utilizing it for more than a third of total sweetener, except during the war rationing period when the amount used occasionally ranged up to one half. The principal problem to be reckoned with in using dextrose is its tendency to crystallize out whenever preservers' products are subjected to cold climates or to refrigeration after the containers have been opened. (As explained above, dextrose is more soluble than sugar at high temperatures, but less soluble at low temperatures.) Opinions concerning the point below which this danger is negligible varied somewhat among the firms surveyed, but generally ranged in the vicinity of 20 to 25 percent of total sweetener. About half of the preservers who used dextrose in combination with sugar preferred to limit it to 20% of total sweetener, while another quarter of them preferred to use as much as 25%. A few firms reported that they considered 33% a safe proportion. Preservers who had used dextrose during the war in amounts equal to one-half the total sweetener reported that this made their preserves sticky and lacking in flavor. When dextrose had been used in amounts approaching 100% of total sweetener, the end product was reported to have become practically a crystalline mass.

The predominating argument for using dextrose in making jams, jellies and preserves was based on its ability to reduce sweetness while maintaining the desired percentage of solids and body of the product. From a quarter to a third of all preservers who used dextrose reported that it was desired principally in order to lessen the tendency of preserved products to be excessively sweet, thereby permitting natural fruit flavors to be more easily identified and enjoyed.

The second most frequently advanced reason given for using dextrose was the price differential under sugar. Since the cost of sweetener is a major factor in the manufacture of such processed food, as jams, jellies, and preserves, many of the preservers believe they have found that the use of corn sweeteners in moderate amounts permitted a lowering of their production costs without any noticeable effect on quality. The differential in price between sugar and corn sweeteners frequently determined whether all sugar would be used, or sugar in combination with one or more of the corn sweeteners. The price differential was considered important also, and in determining whether the cut-out point for corn sweeteners would be at 20% to 25% or as high as 33% of the total sweetener. The fact that dextrose need not be named on the label was another reason frequently mentioned in support of its popularity.

Those who had done laboratory research with combinations of sugar and dextrose usually felt that a combination of the two sweeteners entered the pores of the fruit more readily and gave the product a better color and texture. Dextrose, rather than corn sirup, was found to be more commonly used with sugar because (a) being in granular form, it was easier to use with sugar; (b) it does not add excessive moisture to the batch to be subsequently evaporated; (c) in small lots it is much easier to handle

and store than corn sirup; and (d) it is not associated in the minds of the consumer with imitation jams and jellies as are the corn sirups. Preservers who did not favor the use of dextrose objected to it because of a feeling that its use in amounts sufficient to warrant the extra trouble and expense of handling two different sweeteners lowered the quality of the product. In addition to crystallization at low temperatures when excessive dextrose was used, objections mentioned by preservers included complaints relating to off-flavors and the tendency for the texture of the products to become too sticky.

Combination of Sugar and Corn Sirup - The use of corn sirup, in cominatión with sugar or in combination with a mixture of sugar and dextrose, was reported by only a very small number (8.4%) of the preserving firms interviewed. Three-fourths of the firms using a combination of sugar and corn sirups reported using the latter as 20% of the total sweetener. Most of the preservers using corn sirup in these amounts reported that the quality of products resulting therefrom was, in their estimation, equal to products made with sugar and dextrose in combination, or with sugar as the sole sweetening agent. During the period of scarce sugar supplies, a much larger proportion of the preservers used corn sirup, and the proportion of total sweetener represented by corn sirup often was higher than that which the trade usually considers desirable. Occasionally corn sirup constituted the sole sweetener used. This was particularly true of the small wartime operator who entered the preserving field during this period. Firms which found it necessary to use larger amounts (33 to 50% or more) of corn sirup as a replacement for sugar reported that their products lacked sweetness, that their natural flavors were masked by the heavy dextrine contents of the corn sirups and that the body and texture of products were often gummy or sticky in comparison with those manufactured with higher sugar ratios under peacetime conditions.

Corn sirup was being used for several purposes, two of the more important of which being to cut production costs and reduce sweetness. Corn sirup was said to have an additional advantage which is not possessed by dextrose; namely, no problems of crystallization are encountered when corn sirup is used. Several research institutions and a few preserving firms have experimented successfully with a combination of sugar, dextrose and corn sirup. Such a combination was reported to be economical and to give the desired physical characteristics imparted by corn sweeteners without adversely affecting quality. These firms also indicated that the dual use of the two corn sweeteners with sugar achieved longer preservation of fruit colors (particularly the red pigments), prolonged shelf life of products, and added a gloss or sheen to the fruit which appeals to the buying public. Reasons given for not using corn sirup included the belief that the extra cooking time required to evaporate excess moisture supplied by corn sirup resulted in a degree of caramelization which spoiled the natural flavor of the product. Lack of sweetness in the product was another objectionable feature frequently reported, though some firms believed the cut-down in sweetness resulting

from the use of corn sirups or other corn sweeteners actually brought out the natural fruit flavors more prominently than when only sugar was used. An occasional preserver indicated that fermentation was not as effectively controlled when corn sirups were used with the sugar, attributing this to the belief that the dextrines in corn sirup are slower to penetrate the fruit membranes. The requirement that the presence of corn sirup in preserver's products be declared on the label was reported to be another barrier to its use. 66/

High conversion corn sirups were used by only a small segment of the preservers interviewed. The principal argument advanced in favor of these sirups, in comparison with regular conversion corn sirup, is additional sweetness, which permits replacing 5 to 10% more of total sweetener content than is possible when using regular conversion sirup. Most preservers indicated that they did not consider the high conversion corn sirups sufficiently superior to regular conversion sirups to be worth the additional price. Some of them objected to the lower dextrine content of the high conversion sirup which made it too thin for providing the desired consistency.

Regional Differences in Sweetener Use in Pure Preserved Products - The pattern of sweetener usage in pure preserved items varies considerably in different sections of the United States. The concept of making a high qulaity jam, jelly, preserve, fruit butter or marmalade with sugar alone as the sweetening agent is somewhat more entrenched in the Middle Atlantic States, particularly in the New York-Newark area, than elsewhere. However, three out of four preservers contacted in the North Central States and in the West reported using all sugar. Usage of corn sweeteners in these products was more widespread in the South and in New England than elsewhere. In these areas from 40 to 45 percent of the preservers reported using a combination of sugar and corn sweeteners. Preservers in the South using corn sweeteners usually combined dextrose with sugar, while in New England the most popular combination was sugar and corn sirup. (See table 23).

The relative popularity of corn sirup with preservers in New England cannot be explained by more favorable price relationships in that area because corn sirup is priced in such a manner as to make it cheaper relative to sugar in the North Central area and not in New England. And since the differential between sugar and dextrose is fairly uniform throughout the United States, the greater usage of dextrose in the South cannot be due to price relationships between sweeteners which are more

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66/ Preservers who favor use of corn sweeteners in preserved items currently are attempting to get Federal food and drug standards revised to permit use of corn sirup up to 25% of the total sweetener without label declaration.

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Table 23. - Use of various sweeteners in "pure" preserves, jams, and jellies, by area, 1948: percentage of total plants interviewed using each sweetener

Type of Sweetener Used	New England	Middle Atlantic	North Central	South	West	United States
Refined Granulated Sugar	84.6	86.7	93.8	100.0	100.0	93.1
Liquid Sugar	15.4	13.3	6.2	5.0 1/	0.0	8.3
Total Using Some Form of Sugar	100.0	100.0	100.0	100.0	100.0	100.0
Total Using Only Sugar as the sweetening agent	61.5	80.0	75.0	55.0	75.0	68.0
Dextrose with sugar	7.7	20.0	18.8	40.0	25.0	23.6
Corn sirup with sugar	23.1	0.0	6.2	5.0	0.0	7.0
Dextrose and Corn sirup with sugar	7.7	0.0	0.0	0.0	0.0	1.4
Total using corn sweeteners with sugar	38.5	20.0	25.0	45.0	25.0	32.0

1/ Liquid used with dry granulated.

favorable to dextrose in that region than in others. 67/

Regional differences in the extent to which corn sweeteners are used in the preserving industry appear to be associated more with variations in intensity of competition than to any other specific factor. The greater concentration in New England and the South of firms using corn sweetener is related in part to the smaller volume of business done by the average preserver in this area, where their products must compete price-wise in local markets with nationally known brands manufactured in such areas as New York, Philadelphia or San Francisco by large commercial preservers, whose volume business will better support the cost of using 100% sugar.

Amounts of Sweeteners Used in Imitation Products

Total Sweetener Content - As shown in Table 24, the producers of baker's fillings, 68/ spreads, and imitation jams, jellies, and preserves used from 28 to 70 percent total sweetener in these products. In the imitation jams, jellies, and preserves category, the most common sweetener content was found to be about 55 percent sweetener to 45 percent fruit or other ingredients. This is equal to the ratio used in pure products. A smaller number of firms used 60 and 65 percent sweetener in their imitation products. In fillings and spreads, the total sweetener content varied too widely by types of product and by manufacturer to allow any specific conclusions to be drawn.

Sugar-Corn Sweetener Ratios - Among the imitation products manufacturers interviewed, regular corn sirup was being used by 100 percent of the companies in this group. This sweetener was utilized in ranges running from 5 to 100% of the total sweetener content, and its average use was generally from 60 to 70%. Dextrose and high conversion corn sirups were used very rarely in these products.

Reasons for Use of Corn Sweeteners - A sharp contrast is shown in the use of sweeteners in pure and imitation products. Of those companies reporting the manufacture of both categories, virtually all used either 100% sugar or 80% sugar and 20% dextrose in their pure products, with none indicating the use of corn sirups. Approximately 95% of the firms surveyed reported that one of the primary factors influencing them to use corn sirup in their imitation products was their desire to lower costs. One-half of the companies stated that they felt that corn sirup

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67/ See above pp. 62-78 section on price relationships.

68/ Some preservers interviewed manufactured pure preserves, jams, and jellies for sale to bakers; these products are not considered in this section.

Table 24. - Total Sweetener Content in Imitation Products

Imitation Product	Percent of Sweetener Used		
	High	Low	Average
Preserves, jams, and jellies	65	55	56
Fillings 1/	70	28	-
Spreads	65	25	-

1/ Fruit and doughnut fillings

gave better body, consistency, and texture, while more than one-third stated a preference for corn sirup because it reduced sweetness. Another reason mentioned frequently was the non-crystallizing characteristic of corn sirup, as compared principally with dextrose. The use of corn sirup to give gloss to the product was also considered important. Nearly 20% of the firms making both pure and imitation products stated that they would use regular corn sirup in their pure products if permitted to use it without declaration on the label.

FROZEN FRUITS

Growth of the Frozen Food Industry

While the frozen foods industry is one of the youngest in the field of food processing, many of its products have achieved immense popularity with both commercial users and household consumers. Freezing has been found to be by far the best way of preserving the freshness, natural flavors, natural textures, and nutritional values in many food products. 69/ In 1942, the frozen fruit pack was only about five percent as large as the canned fruit pack, but in 1948 was 14 percent as large as the canned fruit pack. The increase in frozen vegetables was from three percent to approximately 13 percent. 70/ The more important frozen fruit and frozen vegetable items are produced in much more significant volume when compared with their canned counterparts. For instance, frozen berries averaged almost 2½ times the canned pack for the period 1945-48. Frozen strawberries have exceeded in volume their canned counterpart in recent years and are now many times as great. Frozen raspberries are another fruit for which the amount frozen exceeds that which is canned, while frozen red sour pitted cherries have reached a point where they equal around 75-85 percent of canned production. Frozen concentrated citrus juice jumped in Florida alone from 560,000 gallons in 1946-47 to 10,000,000 gallons in 1948-49, and in 1949 was almost equal to the total amount canned. 71/ The rapid growth of the industry has made it an important user of sweetener. The use of sweeteners in the frozen food field is associated chiefly with the freezing of fruits and berries; vegetables are generally frozen with no sweetener added. Therefore, this portion of the study is confined to the use of optional sweeteners in the freezing of fruits and berries, referred to below merely as frozen fruits.

As pointed out in U.S.D.A. Miscellaneous Publication No. 588, fruits which are adapted to freezing are usually divided into two classes, (a) small fruits which can be prepared whole and which consequently do not oxidize or darken easily (i.e. strawberries, raspberries, blueberries, dewberries, loganberries, youngberries and boysenberries); and (b) fruits which require pitting or peeling and which are thereby subject to oxidation when the cut or pitted surfaces are exposed to the air (i.e. cherries,

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69/ U. S. Dept. Agr., PMA. Instructions on Processing for Community Frozen-Food Locker Plants. Misc. Pub. No. 588. March 1946 (Rev. August 1948). p. 1.

70/ U. S. Dept. Com., Off. Dom. Com. Appraisal of the Competitive Position of Frozen Fruits and Vegetables. Industry Report: Canned Fruits and Vegetables. July 1949. p. 45.

71/ See footnote 69.

apricots, peaches, and apples.)

Fruit for freezing may be packed either whole, sliced, chopped, or crushed. While the form in which fruit is packed does not affect directly the amount of sweetening used, it does influence the type of packing media, which in turn, influences the kind of sweetener used.

Dry vs. Liquid Sweetening Media

A frozen food packer may use either a dry or a liquid sweetening medium. A dry pack is made with all sugar or a combination of sugar and dextrose while liquid packs are made with all sugar or a combination of sugar and corn sirup. The choice between a liquid and a dry pack depends primarily on the amount of "bleeding" which occurs from preparing the fruit for processing. A dry packing medium is preferred for fruits, the juices of which bleed excessively, such as sliced strawberries. When a liquid medium is used with fruits of this type, the bleeding of the juices into the processing sirup is apt to make the packing medium too watery or thin. In proposed food standards for frozen fruits, the use of light or medium density sirups would be prohibited in fruits which bleed excessively.

In the freezing of fruits it is necessary for the sweetening material, whether dry or liquid in type, to mix thoroughly with and to coat the surface of the fruits before freezing begins, if it is to constitute a protection against oxidation, shrinkage, and fermentation. When a dry sweetener is used, the fruit is subjected to some shrinkage during the early stages of freezing. The dry sugar or dextrose draws out the natural juices in the fruit cells faster than the fruit absorbs the sirup created by mixture of the juices and the dry packing medium. Recovery in weight lost as a result of this shrinkage is a slow process, and frequently the original weight of the unprocessed fruit is never quite reached. Also, many packers reported that when dry sweeteners are used, the fruit flesh and skins fail to recover their original tenderness entirely, and remain slightly tougher and not as palatable as when the fruit has been processed with a liquid sweetener.

With a sirup pack, where the sweetening medium is already in sirup form before being incorporated with the raw product, all the surfaces of the fruit are immediately coated, and the sweetening medium becomes instantly available to the fruit cells in exchange for their own natural fruit juices without awaiting further dissolution. Thus, since the pores of the fruit are sealed from the air more quickly, liquid packs are more effective than dry sweeteners in the control of oxidation. Also, the sirup becomes instantly available for absorption by the cells of the fruit in exchange for the natural fruit juices and no shrinkage of fruit occurs. In fact, use of a liquid sweetener generally causes an increase in the drained weight of the fruit.

Dr. Joslyn and others at the University of California report that: "The use of sirup has the following advantages:

1. Air discoloration is reduced to a minimum.

2. The sirup is more convenient than the sugar, especially if the latter is to be distributed uniformly throughout the mass of fruit.

3. There is less damage to the fruit during the addition of sirup than during the addition of sugar.

4. A more uniform and attractive pack is obtained as there is little or no change in fruit volume by loss of water from the fruit, and there is no settling of the fruit in the container as occurs in the sugar pack.

5. The sirup is a better aid to preservation during freezing than the sugar. It can be chilled before use and acts as a precooling agent.

6. The texture of the thawed fruit is better.

7. The sirup pack is applicable to all fruits." 72/

Largely because of the above natural advantages of liquid packs, they are somewhat more popular with frozen fruit processors than dry packs. Approximately 60% of all the frozen food processors interviewed indicated a preference for liquid packs whenever the end-use of the product would permit it. Liquid packs are most popular for frozen fruits intended for ice cream, desserts packaged for direct consumption and other products in which the additional water in the packing sirup does not constitute a processing problem. On the other hand, a liquid packing medium was reported to be less popular than the dry sweeteners for frozen fruit intended for pies and other baker's products, or for packs subsequently to be processed into preserves, jams or jellies, because of the extra cooking required to eliminate surplus water in sirup packs. This extra cooking time was reported to result occasionally in discoloration of the fruit pigments or objectionable breakdowns in cellular structure. Other disadvantages of the liquid packs include the expense involved in trasporting the water contained in sweeteners in the sirup form and the cost of evaporating this water.

Frozen food processors indicated that a big advantage of dry sweetened

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72/ Joslyn, M. A. and Hohl, Leonora A. The Commercial Freezing of Fruit Products, Cal. Agr. Exp. Sta. Bul. No. 703. January 1948, p. 22.

packs is their general adaptability to any sort of commercial or household end-use. For this reason, many smaller firms specializing in only one type of pack generally preferred to use dry sweeteners. Furthermore, the greater the tendency for natural fruit juices to bleed into the packing media as a result of the slicing, chopping or crushing of the fruit, the greater the preference for dry sweetening media to absorb the extra liquid and prevent the pack from being too watery or thin when thawed.

Fruit to Sweetener Ratios in Frozen Fruits

The ratio of fruit to sweetener used in processing frozen fruit varies considerably, depending largely upon the acidity of the fruit, the commercial or household end-use to which the product will be put, and the individual preferences of the packer and customer regarding the desired degree of sweetness. Strong acid fruits usually require more sweetener than those which are low in acidity. Smaller amounts of sweeteners are used in freezing bland flavored fruits, such as pears or apricots, where excessive sweeteners could easily mask the more delicate natural flavors. When the fruits are frozen for use in food products to which the user will add additional sweetening, such as sliced frozen apples or peaches packed for use in bakers' pies, the sugar ratios used are likely to be comparatively low. This is in order to allow these users more leeway in flavoring their products to taste. Ratios of 5 to 7 parts of fruit to one part of sweetener are most common for this type of product. On the other hand, fruit intended for use in ice cream, commercial preserved items, desserts packed for use in household consumption, or other products, destined for direct use in the home, usually are packed at a ratio of three or four parts of fruit to one part of sweetener. The proposed Federal food standards for frozen fruits are not specific with regard to the ratios of fruit to sweetener in dry-packs. 73/ In the case of liquid packs, however, they specify the maximum amounts of sirup which can be used in relation to the combined weights of fruit ingredient and packing medium. These range from around 25 to 33% sirup in relation to the total weight of the pack. In terms of fruit-to-sweetener ratios, such a limitation on the permissible weight of the sirup would mean from two to three parts fruit to one part of sweetener. However, in actual commercial practice, members of this industry tend to use considerably less sweetener in relation to fruit than the proposed standards would permit them to use. The standards would, of course, represent legal limits rather than norms used in high-quality merchandise.

A canner or preserver was found to be fairly consistent with respect to the kinds and proportions of sweeteners used in a given line of goods. Since the major portion of a canner's or preserver's volume of production is produced for sale to household consumers under established brand names, it is necessary that he maintain a relatively high degree of uniformity in his product. On the other hand, the greater part of a frozen fruit processor's volume goes into commercial channels for preparation of many

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73/ See above, ch. 3 p. 84 for detailed discussion of proposed Food and Drug standards for frozen fruits.

types of food products. Most packers are constantly accepting individual orders from food processors making a wide variety of products, such as bakers' pies, ice cream, or preservers' products. Each of these orders constitutes an expression of a customer's request for a certain fruit to sweetener ratio, his preference for a dry or liquid pack, and his preference for a specific kind or combination of sweeteners. Consequently, an individual frozen fruit processor uses a considerable number of these ratios, in both dry and liquid packs, and, in the case of liquid packs, a number of sirups covering a wide range in density. Variations in the fruit to sweetener ratio reported by frozen fruit processors surveyed in connection with this study are arranged by types of fruits in Tables 25 and 26 below.

Choice of Sweetening Agents

All Sugar - In processing frozen fruits, sugar is by far the most popular of all sweetening ingredients. Every packer interviewed reported using it in some form, and nine out of 10 of them stated that they used it as their sole sweetening ingredient. There seemed to be little, if any, difference in the acceptability of cane and beet sugar by frozen fruit packers. Approximately 13% expressed a preference for liquid sugar. The principal reasons given for preferring liquid sugar were ease of handling, saving of storage space and reduction in labor costs. If these advantages, plus the discount at which liquid sugar sells, appeared sufficient to outweigh the disadvantages of paying freight charges for water on rail shipments and the installation expense of liquid handling facilities, a packer was favorable toward liquid sugar. This product appeared attractive only to those using largely or entirely a liquid packing medium. A medium-invert type of liquid sugar generally was used. Use of a partially inverted type of liquid sugar or inversion of a part of the sugar during the cooking process was said to be especially useful in tenderizing the skins of such fruits as cherries and peaches and for reducing bacterial action in the packs. Research conducted at the University of California indicated that off-flavors were developed in some fruits, especially when the degree of inversion was above 50 percent. 74/

Frozen fruit packers interviewed who used sugar as the sole sweetening agent reported that they were primarily concerned with sweetness rather than with other chemical or physical properties which sweeteners contribute to the finished product. Because of sugar's greater sweetness in comparison with dextrose and corn sirup, packers considered sugar to be less expensive per unit of sweetness than corn sweeteners. A second reason given by packers for the predominant preference for all sugar is that

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74/ Joslyn, M. A. and Hohl, Leonora A., Op. cit. p. 24.

Table 25 - Fruit to sweetener ratios and sirup densities in frozen fruits: Reported by 31 Processors of frozen fruits, by type of fruit and type of pack, 1948.

Type of Frozen Fruit	Range of Ratios and Densities					
	Low			High		
	Dry Pack		Liquid Pack 1/	Dry Pack		Liquid Pack 1/
	Part Fruit to	Part Sweetener	Sirup in Degrees Brix	Part Fruit to	Part Sweetener	Sirup in Degrees Brix
Sliced apples	7	1	25	3	1	60
Strawberries	5	1	40	2	1	65
Cherries, RSP	5	1	40	2	1	65
Peaches	7	1	30		1	65
Plums and Prunes	5	1	40		1	70
Pears	5	1	30	2	1	70
Apricots	5	1	20	3	1	70
Blackberries	4	1		2	1	68
Raspberries	5	1		2	1	68
Blueberries	6	1		3	1	65
Boysenberries	5	1		2	1	

1/ Packs put up with a liquid sweetener customarily utilize the same proportion between fruit and sweetener as is indicated for a dry pack of the same fruit. The percent of total solids in the packing sirups and shown hereunder is determined by the Brix hydrometer.

Source: Surveys, RMA Project [illegible]:c-137

Table 26. - Fruit to sweetener Ratios and sirup densities most preferred by principal end-users: Reported by 31 processors of frozen fruits, by type of fruit and type of pack, 1948

Type of Frozen Fruit	Bakers		Ice-cream Mfrs.		Preservers		Retail Domestic Packs	
	Dry Pack	Liquid Pack 1/	Dry Pack	Liquid Pack 1/	Dry Pack	Liquid Pack 1/	Dry Pack	Liquid Pack 1/
Sliced apples	7-1 5-1	25					3-1 4-1	40-50
Strawberries			3-1 4-1	50	3-1 4-1	50	3-1 4-1	50
Cherries, RSP	5-1	50			5-1	50	4-1 5-1	50
Peaches	7-1	30	4-1 5-1	45	3-1 4-1	45	3-1 4-1	45
Plums and Prunes					4-1	55	3-1 4-1	55
Pears					4-1	45	3-1 4-1	45
Apricots					3-1 4-1	45	3-1 4-1	45
Blackberries					2-1 3-1	67	3-1 4-1	50
Raspberries			6-1	40	3-1 4-1	50	3-1 4-1	50
Blueberries	6-1 5-1	40					4-1	50

1/ Sirup in Degrees Brix. Packs put up with a liquid sweetener customarily utilize the same proportion between fruit and sweetener as is indicated for a dry pack of the same fruit. The percent of total solids in the packing sirups and shown hereunder is determined by the Brix hydrometer.

Source: Surveys, RMA, Project RM:c-137

Table 27. - Sweeteners or combinations of sweeteners used by processors of frozen fruits, 1948

Sweeteners or Combinations of Sweeteners	Processors Reporting Use	
	Number	Percent
100 percent sugar	28	90
Sugar and dextrose	2	7
Sugar and corn sirup 1/	1	3
Total Processors	31	100

1/ High conversion corn sirup

crystallization problems are not so pronounced as when a combination of sugar and dextrose is used. Since sugar is the only sweetening ingredient which can be used by itself to satisfy all of the functions of a sweetener in frozen foods, many processors indicated that they preferred to use it exclusively rather than complicate their storage and labor problems or increase the chance of error in the plant through the use of more than one sweetening agent.

As with many other food processors, psychological factors appeared to have a noticeable effect upon a frozen fruit packer's choice of sweetener. Historically, sugar as the sole sweetener has been associated with quality merchandise in the minds of many producers and commercial users of frozen fruits. Many packers themselves appear to be shifting away from this view and seem willing to accept the results of technological research. On the other hand, many commercial users of frozen fruits are reluctant to accept this view, and insist that products supplied them be sweetened with 100 percent sugar.

Combinations of Sugar and a Corn Sweetener - Only 10 percent of all processors surveyed reported commercial use of corn sweeteners. (See table 27.) However, a significant number indicated that they either were experimenting with them or were expecting to begin use of them in the near future. Much experimental work is under way in food technological laboratories throughout the country with respect to the use of corn sweeteners in frozen fruit packs. In fact, the extent to which qualified research has gone in analyzing the results which can be achieved by the use of corn sweeteners in frozen fruits is far advanced in comparison with the actual practice of commercial packers. When sugar supplies were limited, about a third of the packers who normally use only sugar reported occasional use of small amounts of dextrose or corn sirup in order to stretch their sugar rations. The other two-thirds reported that they preferred to curtail production when necessary rather than use any sweetener other than sugar.

Dextrose and high-conversion corn sirups were the only two corn sweeteners reported in current use by processors of frozen fruits. Opinion as to the merits of either would indicate that they were about equal in popularity. Dextrose was preferred chiefly when processors used dry packs, and the high-conversion sirups were preferred when they used liquid packs. The amounts of either of these did not in any case exceed 33 percent of the total sweetener. Whereas there are at present no Federal food and drug standards with respect to the use of sweeteners in frozen foods, pending or proposed standards for these products appear to have an effect upon the sweetener usage policy of many companies. Many frozen food processors reported an interim policy regarding sweetener usage which is in line with the proposed regulations, in order to avoid any subsequent changes in manufacture which might affect the market acceptability of their products. In general, the proposed standards would permit the use of all the corn sweeteners but would limit their use to no more than one-third of total sweetener. (See above pp. 82-83 for fuller discussion of the proposed standards for frozen foods.)

Sugar and Dextrose - Seven percent of all frozen fruit processors surveyed were currently using dextrose, principally because they believed that they were effecting a saving in production costs without altering the qualities of flavor and texture in their packs. As a general rule, these packers were using dextrose to the extent of 20 to 25% of total sweetener. Most of them were convinced that there was no discernible difference in the appearance of fruit frozen with sugar and dextrose and that frozen with sugar alone. They also stated that flavor was actually improved because of a reduction in total sweetness, which tended to accentuate natural fruit flavors.

The principal disadvantage of using dextrose in the frozen fruit industry was reported to be its tendency to crystallize. A majority of the packers reported that whenever dextrose was used in excess of 25 to 33% of total sweetener crystallization became a serious problem. Although much research in this field indicates that the danger of crystallization is minimized when a ratio of 20% dextrose and 80% sucrose is used, some processors reported difficulties in preventing dextrose from crystallizing even when used in this moderate ratio. Some packers indicated they were reluctant to use dextrose because some of their customers have expressed a dislike for it. Such dislike was reported to be due to the belief that the darkening of fruit pigments and presence of off-flavors in products might be associated with the use of dextrose.

Sugar and Corn sirup - Only a very small proportion (3.2%) of the frozen fruit packers interviewed reported current use of corn sirup. Those processors using corn sirup reported they liked the sheen or gloss which this sweetener imparted to fruits when thawed, thereby increasing their appeal to customers. Furthermore, if a firm had installed a system for using liquid sugar, the companionate use of corn sirup was found to be physically more advantageous than the use of dextrose. Aside from its lower sweetening properties, the primary disadvantages were reported to be in-plant handling difficulties and the dextrin-like flavor which it imparted to frozen fruits even when used in low percentages.

Corn sirup solids were not found to be in use at the time of the survey, nor was it reported that this product was used by any packer during the war rationing period. Manufacturers indicated that corn sirup solids gave results similar or identical to those obtained with regular corn sirup. The higher price of this product, together with the difficulties which occur in handling the material whenever parts of bags are left unused, are additional barriers to general use of the solids by fruit packers.

Inasmuch as the use of dextrose in frozen fruits is limited to around 20 to 33% of total sweetener, many processors and food technologists have turned to experiments with the corn sirups, in order to determine whether fruit packs of satisfactory quality can be made by use of higher percentages of these corn sweeteners in combination with sugar.

The results of a recent series of experiments by technologists of the Food Technology Department at the Oregon Agricultural Experiment Station, were generally quite favorable to the use of corn sirup in frozen foods. In a recent article on food freezing, 75/ the authors draw the following conclusions: Use of a 40-50 degree Balling Sirup on frozen fruit, to replace 40-50 percent of the sucrose solids with corn sirup (which in these experiments were sirups containing 90-95% regular conversion corn sirup and 5-10% refiners sirup) resulted in a significantly higher drained fruit weight and a frozen fruit superior in flavor, texture and color. In addition, these experiments indicated that there was less oxidation of the fruit when it was packed with a blend of sugar and corn sirup than when it was packed with either straight sugar or straight corn sirup.

Experiments of the same character conducted at the University of California tend to agree in part, though not entirely, with the work done at Oregon State College. Dr. Joslyn, of the California Agricultural Experiment Station, reports that:

> "Commercial glucose sirups (low conversion corn sirups) were found to be superior to dextrose sirups in color retention, but fruit packed in these sirups had a slightly objectionable flavor. The high conversion corn sirups also were satisfactory in color-retention ability. Several fruits retained more of their natural color in these sirups than in sucrose sirups of the same strength, but developed a noticeable foreign flavor. Mixtures of high conversion corn sirups with cane in the proportion of 1 part corn sirup solids to 3 of sucrose, however, were equal to cane sugar solution." (Ibid.)

It can be seen that while these two technologists are in agreement that sirups made by blending sugar and corn sirup are as acceptable as all-sugar sirups in packing frozen fruits, they disagree as to the type of corn sirup and the percentages of the two ingredients which produce the best product. California research technicians prefer to blend 25% high conversion sirups with 75% sugar, while those in Oregon believe that blends of regular conversion sirups and sugar, with almost double this proportion of corn sirup, were equal to, or superior in flavor to all-sugar packs. In comparing these differences of opinion on the research level with those obtained from food processors on the operating level, it is interesting to note that only the high conversion type of corn sirup

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75/ Sather, Lois and Wiegand, E. H. Food Freezing: The Application of Corn Sirup in the Freezing Preservation of Fruit, in Quick Frozen Foods. May 1948. pp. 81-83.

was reported being used by frozen fruit packers utilizing a corn sirup in forming a liquid packing medium, and that the proportions reported were never in excess of 35% total sweetener. The preference for high conversion sirups in these products was reported to be due to their ability to prevent crystallization in frozen fruits and at the same time supply a greater amount of sweetness than would be the case when using the regular conversion sirup.

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ICE CREAM, SHERBETS AND ICES

The Part Which Sweeteners Play in the Manufacture of Ice Cream, Sherbets and Ices

Ice Cream - Ice cream is a frozen or semi-frozen product customarily manufactured from a combination of two or more of the following ingredients: Cream, milk, or other suitable milk products; eggs; sugar, dextrose, corn sirup, glucose sirup, or invert sugar; water; flavoring material; coloring material; and a stabilizer. As used herein, the term ice cream excludes novelty ice creams, custards, and other products whose ingredients may vary considerably from the ingredients of regular types of ice cream. Flavor, coloring and stabilizer form a relatively minor portion of an ice cream mix by weight and eggs are seldom used in regular vanilla, fruit or chocolate ice cream. Hence, total solids in the average ice cream mix consist almost entirely of milk fat, non-fat milk solids (serum solids) and sweetener. These three ingredients amount to about 38 percent of the total weight of ice cream. Thus, sweeteners in ice cream are important not only for their sweetening power, which contributes to the flavor and palatability of the product, but also for their contribution to the solids content.

Most manufacturers believed that the sweetener content should amount to 15 or 16 percent of the mix. Total sweetener content varies much more by grade than by flavor of ice cream. Approximately three-fourths of the manufacturers interviewed reported that the total sweetener content was the same for corresponding grades of vanilla, fruit and chocolate ice creams. In the case of vanilla ice cream, 83 percent reported that 15 or 16 percent sweetener was used for all grades or that this was the lowest percentage of sweetener used in that type of ice cream. Other producers were using 16 percent or more, when added sweetness was desired in a different grade or kind of ice cream. For example, in fruit mixes 77.6 percent, and in chocolate, 63.4 percent of the manufacturers reported the use of 15 or 16 percent of total sweetener, but percentages greater than 16 percent were also being used in these kinds of ice cream.

A good ice cream is developed by an individual manufacturer from a formula in which the proper balancing of the amounts of each of the ingredients has been attained.

> "There are four standards by which a perfect ice cream is measured, viz., its flavour, texture, richness and appearance. The most important is flavour, by which is meant not the taste imparted to it by the addition of vanilla or some other flavouring agent, but the actual flavour given to it by the dairy products and sugar which form its main components." 76/

76/ Feltham, Leonard R. M. The Making of Ice Cream. London. Heywood and Co., Ltd. 1934. p. 101.

A study of the data reported by ice cream manufacturers interviewed reveals that the average total milk solids used by all manufacturers is about the same for vanilla, fruit and chocolate ice creams (Table 28). Butterfat averages vary somewhat with the flavor, while non-fat milk solids are essentially the same for each flavor.

Table 28 - Butterfat, non-fat milk solids and sweetener content in ice creams: Average of percentages reported by 123 manufacturers - United States, 1948

Type of ice cream	Butterfat (percent)	Non-fat milk solids (percent)	Total sweetener (percent)	Total milk solids and sweetener (percent)
Vanilla	12.8	10.8	15.3	38.9
Fruit	12.6	10.8	15.6	39.0
Chocolate	12.9	10.8	16.0	39.7

The averages shown in Table 28 reflect the inclusion of butterfat and sweetener contents in other than standard grades of ice cream, i.e., grades which volumewise are of lesser importance than the standard grades. The great majority of formulas reported are concentrated around the combination of 12 percent butterfat with 15 or 16 percent sweetener. A content of 10 to 11 percent non-fat milk solids was reported with almost all of these combinations. Thus, the average standard ice cream produced in the United States probably contains about 12 percent butterfat, 10 to 11 percent non-fat milk solids and 15 to 16 percent sweetener.

A large number of manufacturers keep sweetener content constant when butterfat percentages are varied for different grades of ice cream. In most of these cases, non-fat milk solids are decreased when butterfat is increased, in order to retain the same percentage of total solids in the mix. Other producers vary sugar percentages directly with any change in butterfat content; that is, if butterfat is increased or decreased, sugar is also increased or decreased. Generally, in this case, non-fat milk solids vary inversely with the combined butterfat and sweetener content in order to keep total solids about constant. In a few plants only sweetener content is increased when butterfat content is decreased. Whereas in many plants sweetener content is kept constant with a change of butterfat content in the same type of ice cream, a substantial number of these plants use higher percentages of both sweetener and butterfat in chocolate ice cream than are used in fruit and vanilla ice cream. Chocolate ice cream was said to require a higher percentage of sweetener in the mix to cut the sharpness of the chocolate flavor.

Sherbets and Ices - Fruit ices, or water ices, are the frozen product which may contain water; sugar, dextrose, corn sirup solids, corn sirup and other sweeteners or combinations thereof; natural fruit, fruit flavor or fruit juice; and artificial coloring; about 0.35 percent acid (citric, tartaric or lactic) and; approximately 0.5 percent stabilizer. Sherbets, or milk sherbets, contain the above ingredients with the addition of milk, milk products or plain ice cream mix.

As in ice creams, sweeteners are important in sherbets and ices for their sweetening qualities. However, in sherbets and ices, sweeteners also constitute practically all of the total solids content and are of prime importance to the physical consistency of these products.

The total sweetener content of sherbets or milk sherbets ranged from 20 percent to 41 percent and averaged 28.4 percent of the weight of the total mix. Use of about 30 percent total sweetener in the mix was preferred by the majority, while an additional one-fourth of the group preferred 28 percent (See Table 29). Less than one-tenth of the sherbet manufacturers used over 30 percent total sweetener in these products.

Table 29 - Total sweetener content of sherbets and ices: Frequency of usage by manufacturers reporting production, 1948

Total Sweetener Content (percent of mix)	Manufacturers using percentages listed in:			
	Sherbets		Ices	
	Number	Percentage	Number	Percentage
20-27	20	22.7	16	19.1
28	23	26.1	9	10.7
29	6	6.8	6	7.1
30	31	35.3	39	46.4
31-42	8	9.1	14	16.7
Total Manufacturers Reporting	88	100.0	84	100.0

The total sweetener content of ices ranged from 20 percent to 42 percent and averaged 29.4 percent of the total mix by weight. Most manufacturers reported the production of both sherbets and ices and, of these manufacturers, about one-fourth of them preferred a higher total sweetener content in ices than in sherbets. Thus, slightly less than half preferred 30 percent while one-sixth of them preferred over 30 percent total sweetener in this type of frozen dessert.

Butterfat in sherbets ranged from none at all to five percent in the mix. For those who used butterfat, this ingredient averaged 3.0 percent in the mix, but many preferred 4 percent, primarily in milk sherbets. Non-fat solids ranged from "none" to 14 percent in sherbets of all types, and averaging 6.8 percent for sherbets containing the non-fat milk solids, and there was some concentration of usage around 8 percent, particularly in the case of milk sherbets.

The Use of Sugar in Ice Cream, Sherbets and Ices

Ice Cream - Approximately 38 percent of the manufacturers interviewed in 1948 reported the use of cane or beet sugar as the only sweetening agent in ice cream; the others were using a combination of sugar with either dextrose, corn sirup or corn sirup solids. 77/

Approximately 40 percent of the manufacturers reporting 100 percent sugar usage in ice cream indicated that they used sugar as the sole sweetener because they believed a higher quality product resulted. Among the quality factors mentioned were body, texture and taste. One-tenth of these manufacturers reported that their sweetener preference was based on the superior sweetening property of sugar. Approximately 35 percent of the all-sugar users indicated that plant operations influenced their choice of sweetener. More than one-half of these manufacturers preferred the convenience of handling one sweetener only, viz. dry sugar, or stated that their volume of sales was too small to warrant the use of another sweetener. The balance of the 35 percent were using liquid sugar and indicated that they would prefer to use this sweetener alone for convenience of handling and mixing.

Other reasons reported as factors determining the use of 100 percent sugar in ice cream were as follows:

a. The parent organization required or recommended that sugar alone be used.

b. A prepared mix was purchased from another company which used 100 percent sugar.

c. Ice cream formulas were historically based on the use of sugar only and a change of formula was undesirable.

d. Sugar cost less per unit of sweetness than corn sweeteners.

e. Consumers were thought to prefer ice cream containing sugar as the sole sweetening agent.

77/ Honey was used as the only sweetener in ice cream manufactured for a particular religious group which does not use sugar in their foods. Such ice cream is not considered in this report.

Sherbets and Ices - Only one-tenth of the plants manufacturing sherbets and ices used 100 percent sugar in these products; the others used a combination of sugar and one of the corn sweeteners. Most of those reporting 100 percent sugar usage in sherbets and ices stated that the convenience of handling a single sweetener was the primary determining factor. Manufacturers who preferred all-sugar formulas reported that no crystallization of the sweetener was likely at the concentration used.

The Use of Corn Sweeteners in Ice Cream, Sherbets and Ices

The Number of Manufacturers Using Corn Sweeteners - Of all manufacturers interviewed, both large and small, 62 percent reported the use in ice cream of a combination of sugar and one or more of the corn sweeteners. Table 30 illustrates the preferences for each of the four types of corn sweeteners, the majority using either dextrose, corn sirup solids, or equal amounts of the two. Less than one-fifth of those using corn sweeteners preferred the high-conversion type of corn sirup, and use of regular corn sirup was found to be relatively negligible.

Table 30 - Corn sweeteners used by manufacturers reporting the production of ice creams, 1948

Corn sweeteners used with sugar in ice creams	Manufacturers reporting sweetener usage		
	Number	Percent of corn sweetener users	Percent of total manufacturers
Dextrose	35	46.1	28.7
Corn sirup solids	22	29.0	18.0
Dextrose and corn sirup solids	2	2.6	1.6
High-conversion corn sirup	14	18.4	11.5
Regular corn sirup	3	3.9	2.5
Total using corn sweeteners	76	100.0	62.3
Total manufacturers	122	-	100.0

Almost 9 out of 10 of the manufacturers of sherbets and ices reported the use of a combination of sugar with one or more of the corn sweeteners. (See Table 31) Most of those making ice cream as well as sherbets and ices preferred to use a combination of sugar and corn sweetener in the sherbets and ices, even though they used 100 percent sugar in ice cream. Of those preferring some corn sweeteners in sherbets and ices, more than one-half reported the use of dextrose with sugar, the next largest group preferring corn sirup solids.

Table 31 - Corn sweeteners used by manufacturers reporting the production of ices and sherbets, 1948

Corn sweeteners used with sugar in sherbets and ices	Manufacturers reporting sweetener usage		
	Number	Percent of corn sweetener users	Percent of total manufacturers
Dextrose	46	50.5	44.2
Corn sirup solids	21	23.1	20.2
Dextrose and corn sirup solids	2	2.2	1.9
High-conversion corn sirup	19	20.9	18.3
Regular corn sirup	3	3.3	2.9
Total using corn sweeteners	91	100.0	87.5
Total manufacturers	104	-	100.0

Sugar-Corn Sweetener Ratios - The majority of manufacturers using corn sweeteners in frozen desserts preferred a combination of 75 percent sugar and 25 percent corn sweeteners. Over two-thirds of the corn sweetener users preferred a combination of sweeteners in which the proportion of corn sweeteners was from 20 to 29 percent of the total sweetener content. A somewhat higher proportion of the manufacturers of sherbets and ices than of those making ice cream preferred combinations in which ratio of corn sweetener to total sweetener was 30 percent or above.

During the recent war period, a number of manufacturers either began to use corn sweeteners in ice creams for the first time or increased the proportion of this type of sweetener. Marketable ice cream was reported to have been produced using corn sweetener to replace between 30 and 50 percent of the total sweetener content, but 50 percent was the upper limit for the replacement. In sherbets and ices, however, corn sweeteners were used in amounts up to 75 percent of total sweetener content, with reportedly satisfactory results. It is indicated, therefore, that the upper limit for replacement of sugar by corn sweeteners is about 50 percent of the total sweetener content in ice cream and 75 percent in sherbets and ices. However, in actual commercial practice at the time of the survey, the proportion of corn sweetener used was much lower.

Advantages and Disadvantages of Using Corn Sweeteners - Among the advantages of including corn sweeteners as one of the ingredients in frozen desserts, the one most frequently mentioned was the favorable effect of such sweeteners on the physical characteristics of the product. Of the total manufacturers interviewed, almost two-thirds stated that a corn sweetener improved the body and texture of one or more of the frozen desserts. In the case of ice cream, the corn sweeteners were believed to give a smoother product and provide a better "melting down" consistency, when used in

amounts not considered excessive. Many producers of sherbets and ices emphasized that the value of corn sweeteners in these products was enhanced by their ability to prevent or inhibit bleeding 78/, granulation or crystallization, and separation of the ingredients in the product.

The relative sweetness of sugar and corn sweeteners plays an important role. A manufacturer who uses 100 percent sugar usually desires a sweeter product, or he desires a sufficiently sweet product with a lower total sweetener content. However, when more body is desired without increasing the sweetness, or a reduction of sweetness without sacrificing body, a combination of sugar with corn sweeteners is indicated.

The majority of those who had used corn sweeteners believed that when used in limited amounts no impairment of flavor or taste was noticeable. In many instances, individuals stated that corn sweeteners tended to bring out the natural flavors, carry fruit flavors better, or make the product more palatable. Those who considered that the effect of a corn sweetener was to impair quality generally reported that they had used the corn sweetener in amounts greater than 30 percent of the total sweetener content. When used in relatively large proportions, corn sweeteners were said to flatten or deaden or overpower the natural flavors. Because of differences in freezing temperatures when sugar is partially replaced by corn sweeteners, it is often necessary to change the temperature regulation on freezing and holding cabinet equipment.

The lower price of corn sweeteners was reported to play a secondary role. Where use of a certain proportion of corn sweetener was preferred by manufacturers of ice cream, the physical characteristics imparted to the product of ice cream were stressed rather than savings in cost through use of the corn sweeteners. While a few stated that price played a decisive part in their decisions, a larger number declared that in ice cream some amount of corn sweetener would be wanted anyway for its physical properties. In the case of sherbets and ices, a greater number of manufacturers gave more consideration to relative prices, as competition was found to exist between sugar and corn sweeteners, and also between the different types of corn sweeteners. Thus, price and price differentials between sweeteners played a minor role in the use of corn sweeteners in the higher-priced frozen desserts and a more decisive role in the lower-priced sherbets and ices.

Dextrose - Dextrose was reported to give body to a frozen dessert without excessive sweetness. Its greatest advantage as a sweetening agent seems to be in the sherbets and ices. When more body is wanted in sherbets and ices, or 100 percent sugar is thought to give too sweet a product, the manufacturers believe that corn sweeteners other than dextrose give

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78/ Bleeding is a term generally used to describe the separation of liquid from the solids.

body, but insufficient sweetness in products containing a relatively large proportion of corn sweetener. Dextrose, the sweetest of the corn sweeteners, was preferred over corn sirup solids and corn sirup by these manufacturers, and a number of producers were using dextrose in sherbets and ices although they used another corn sweetener in ice creams.

When used in ice cream, dextrose was said by some to present a problem of crystallization not encountered when use was made of the other corn sweeteners. While some believed that dextrose itself crystallized in ice creams, a few manufacturers believed that sandiness could be attributed to lactose crystallization and was more noticeable in ice cream containing dextrose.

A number of manufacturers mentioned that dextrose has a lower freezing temperature than sugar, and reported the necessity of resetting temperature gauges when this sweetener was employed in frozen desserts.

Many manufacturers stated that they would not consider the use of dextrose unless the price differential between dextrose and sugar was widened sufficiently to enable enough savings in ingredient costs to warrant handling two sweeteners. Some who were favorably disposed toward using dextrose were not doing so because they could obtain one of the other corn sweeteners at a lower price.

Corn Sirup Solids - Smaller manufacturers using corn sirup solids in place of corn sirup were almost unanimous in advocating the use of this sweetener in frozen desserts as a means of improving body and texture. This was especially true in ice cream, where use of corn sirup or corn sirup solids was said to impart a desirable consistency to the product. In a few instances, it was stated that use of the solids resulted in an excessive amount of body, if sweetness were to be maintained. About a third of the solids users expressed a preference for this material because it permitted an increase in body with a reduction in sweetness. Comments were mostly negative concerning the advantages of using corn sirup solids for better flavor. While a few users of this sweetener believed that solids improved the flavor of frozen desserts, the majority of comments indicated that corn sirup solids were believed to have no noticeable effect when used within certain replacement limits. An amount not in excess of 30 percent of total sweetener was given as the approximate limit.

A few manufacturers who preferred corn sirup solids were using dextrose in areas where dextrose was cheaper.

When a corn sweetener was used with granulated sugar in frozen desserts, smaller manufacturers almost always reported a preference for dextrose or corn sirup solids, for the convenience of handling bag sweeteners only. In this connection, dextrose was often preferred over corn sirup solids, since the solids are hygroscopic by nature, and have a tendency to absorb moisture and become sticky when exposed to the air. A few reported that this sweetener also tended to become lumpy in mixing.

Products made with corn sirup solids had been found to have a higher freezing temperature than those made with sugar. While some believed that this required a resetting of temperature regulators when this sweetener was used, others reported that the higher freezing temperature with corn sirup solids enabled freezing of the mix in a shorter length of time. 79/

High-Conversion Corn Sirup - High-conversion corn sirup was reported to impart smoothness and a desirable consistency to ice cream and prevent or inhibit bleeding and crystallization in sherbets and ices. However, a few producers stated that when too much of this sweetener was used a sticky product resulted. High-conversion corn sirup was liked when both body and sweetness were desired, and where it was rejected as a supplementary sweetener, operational factors were generally responsible. A few manufacturers used it as a means of cutting costs, because it generally is cheaper than dextrose or corn sirup solids.

Most manufacturers who used granulated sugar in frozen desserts had rejected the corn sirups primarily because of the difficulty in handling liquid sweeteners in barrels or drums. Where facilities for handling liquid sweeteners had been installed by the larger manufacturers no difficulties were experienced and corn sirup was preferred over the other corn sweeteners because of its lower price and for convenience in handling and mixing. A number of manufacturers stated that they would prefer that sweeter high-conversion corn sirup if proper handling facilities were installed and they could purchase the sirup in tankcar lots. Others stated that they would prefer some grade of corn sirup to other corn sweeteners if a pre-mixed sugar and corn sirup combination could be purchased.

Regular Corn Sirup - Use of regular corn sirup in frozen desserts was reported to give somewhat more body and less sweetness to such products than results from use of the same quantity of the high-conversion sirup. Accordingly, when corn sweeteners are used, it was reported that use of too great a proportion of regular corn sirup may give an excessive amount of body with insufficient sweetness. Except for the water which it contains, regular corn sirup has approximately the same composition as corn sirup solids and may be used in corresponding proportions with equally good results. The unit cost is less than for the other corn sweeteners but the sirups are considered more difficult to handle on a small scale than dextrose or corn sirup solids.

79/ For additional information regarding relative freezing temperature of the primary sweeteners, see pages 57-58.

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UNITED STATES DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION

1.Project No.RM:c-137
2.Branch Sugar
3.Agency PMA

RESEARCH AND MARKETING ACT

4. RMA Work Project Title: VII: Analysis of Demand and Consumer Preferences for Agricultural Products

(a) RMA Subproject Title: Competitive Relationship between Corn Sugar and Sirup and Cane and Beet Sugars and Sirups.

5. Act Title: Title 11, Sec. 204 (a).

6. (a) Problem and Needs: For several years the production and use of corn sugar and sirup have been increasing. This trend was rapidly accelerated during the recent period of shortage of sucrose. Another recent development is expanded use of liquid cane and beet sugar rather than dry sucrose. Other shifts in use of sweetening agents also have occurred. Specific information on the extent and nature of these increases and shifts, on factors governing the choices of types of sweetener, and other factors determining the markets for corn and cane and beet sugars is not now available. A research project to determine this information for various types of industrial users is needed. Information gained as a result of such a project will be helpful to all segments of the cane and beet sugar and corn sugar industries in development of production and marketing plans; to the Department in its operational programs and planning activities; and to the consuming public.

(b) Object: The objective is to determine quantitatively the use of corn sugar or sirup and dry or liquid cane and beet sugar as sweetening agents by various industrial users; to ascertain the factors governing the choice of use of sweetener; to study the competitive relationship between liquid sugar and corn sirup and the probable effect of the expanding liquid sugar industry on both the dry sucrose and corn sirup industries; and to explore the problem of probable long-time market demand for the various types of sweeteners.

(c) Plan: Determine from Government and trade sources the statistics on production and use by types of industries for dry and liquid sucrose and corn sugar and sirups. Supplement these statistics with original data collected by means of questionnaires and interviews whenever necessary. Assemble information from appropriate Government and trade sources relative to the chemical properties, sweetening, nutritive values, and other characteristics of dry and liquid sucrose and corn sugar or sirup which effect the choice of sweetener. Analyze statistically the factors governing the price relationships between corn sugar or sirup and sucrose and ascertain

by questionnaires and inteviews the degree to which relative prices govern the choice of sweetener. Explore the question of consumer preference for one type of sweetener over another for various uses. Estimate the production and consumption potentials for corn and sucrose sweeteners under varying conditions of prices and demand conditions. Information collected and analyses performed will be summarized in report form for possible publication and subsequent use.

Approved:

_____ Director, Sugar Branch _____

_____ Asst.Admr. for Mktg., PMA _____

Form SU-64
(1-24-50)

U. S. DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION

BUDGET BUREAU NO. 40-R1903.1
APPROVAL EXPIRES JANUARY 31, 1951

COMPANY

QUARTER

SUGAR DELIVERIES BY TYPE OF BUYER

IMPORTANT: *SEE INSTRUCTIONS ON REVERSE SIDE BEFORE EXECUTING THIS FORM*

PRODUCT OR BUSINESS OF BUYER	NEW ENGLAND		MIDDLE ATLANTIC		NORTH CENTRAL		SOUTH		WEST		TOTAL UNITED STATES	
	CRYSTAL-LINE (100 LB. BAGS)	LIQUID (100 LBS. REFINED EQUIV.)	CRYSTAL-LINE (100 LB. BAGS)	LIQUID (100 LBS. REFINED EQUIV.)	CRYSTAL-LINE (100 LB. BAGS)	LIQUID (100 LBS. REFINED EQUIV.)	CRYSTAL-LINE (100 LB. BAGS)	LIQUID (100 LBS. REFINED EQUIV.)	CRYSTAL-LINE (100 LB. BAGS)	LIQUID (100 LBS. REFINED EQUIV.)	CRYSTAL-LINE (100 LB. BAGS)	LIQUID (100 LBS. REFINED EQUIV.)
1. Bakery and allied products, cereals and cereal products												
2. Confectionery and related products												
3. Ice cream and dairy products												
4. Beverages												
5. Canned, bottled and frozen foods, jams, jellies, preserves, etc.												
6. Multiple and all other food uses												
7. Non-food uses												
8. Hotels, restaurants, institutions												
9. Wholesale grocers, jobbers, sugar dealers												
10. Retail grocers; chain stores, super markets												
11. All other deliveries, including deliveries to Government agencies												
12. Total deliveries												
13. Deliveries in consumer-size packages (less than 100 lbs)		–		–		–		–		–		–

Form GRAIN-288
(1-25-49)

U. S. DEPARTMENT OF AGRICULTURE
PRODUCTION AND MARKETING ADMINISTRATION

BUDGET BUREAU NO. 40-R1907
APPROVAL EXPIRES FEBRUARY 28, 1950

COMPANY

QUARTER

DEXTROSE SALES, DOMESTIC, BY TYPE OF BUYER
(IN 100-POUND BAGS)

PRODUCT OR BUSINESS OF BUYER	NEW ENGLAND	MIDDLE ATLANTIC	NORTH CENTRAL	SOUTH	WEST	TOTAL UNITED STATES
1. Bakery and allied products; cereals and cereal products						
2. Confectionery and related products						
3. Ice cream and dairy products						
4. Beverages						
5. Canned, bottled, & frozen foods; jams, jellies, preserves, etc.						
6. Multiple and all other products						
7. Non-food products						
8. Wholesale grocers; jobbers; retail grocers, chain stores; super markets						
9. Other sales including sales to Government agencies						
Total domestic sales						

Table 32. - Cane Sugar Refineries, by Company and Location, United States 1950-51

Company	Refinery Location
American Sugar Refining Company	Brooklyn, N. Y.
	Boston, Mass.
	Baltimore, Md.
(Franklin Sugar Refinery)	Philadelphia, Pa.
(McCahan Sugar Refinery)	Philadelphia, Pa.
	Chalmette, La.
American Molasses Company (Nulomoline)	Chicago, Ill.
(Nulomoline	San Francisco, Cal.
(Nulomoline & Sucrest)	New York, N.Y.
J. Aron and Company	Tallieu, La.
California & Hawaiian Refining Corp. Ltd.	Crockett, Cal.
(Western Refinery)	San Francisco, Cal.
Colonial Sugars Company	Gramercy, La.
Fellsmere Sugar Producers Association	Fellsmere, Fla.
Godchaux Sugars, Inc.	Reserve, La.
Henderson Sugar Refining, Inc.	New Orleans, La.
Imperial Sugar Company	Sugar Land, Texas
Industrial Sugars, Inc.	St. Louis, Mo.
Inland Sugars, Inc.	Milwaukee, Wisc.
Krim-Ko Corporation	Chicago, Ill.
Liquid Sugars, Inc.	Indianapolis, Ind.
Louisiana Liquid Sugars, Inc.	Jeanerette, La.
National Sugar Refining Company	Long Island City, N.Y.
(Pennsylvania Sugar Division)	Philadelphia, Pa.
Pepsi-Cola Company	New York, N.Y.
Refined Syrups & Sugars, Inc.	Yonkers, N.Y.
Revere Sugar Refinery	Boston, Mass.
Savannah Sugar Refining Corp. (Port Wentworth)	Savannah, Ga.
South Coast Corporation	Mathews, La.
Southdown Sugars, Inc.	Houma, La.
Sterling Sugars, Inc.	Franklin, La.
Tea Garden Products Company	San Francisco, Cal.
Total Refineries	32

Table 33. - Location of Beet Sugar Factories, United States, 1950-51

Factories Operating, 1950-51

California

1. Alvarado
2. Carlton (Brawley)
3. Betteravia
4. Clarksburg
5. Dyer
6. Hamilton City
7. Manteca
8. Oxnard
9. Spreckels
10. Tracy
11. Woodland

Colorado

1. Brighton
2. Brush
3. Delta
4. Eaton
5. Fort Collins
6. Fort Morgan
7. Greeley
8. Johnstown (molasses)
9. Longmont
10. Loveland
11. Ovid
12. Rocky Ford
13. Sterling
14. Sugar City
15. Swink
16. Windsor

Idaho

1. Idaho Falls
2. Nampa
3. Preston
4. Rupert
5. Twin Falls

Iowa

1. Mason City

Kansas

1. Garden City

Michigan

1. Alma
2. Bay City
3. Blissfield
4. Caro
5. Carrollton
6. Croswell
7. Lansing
8. Menominee
9. Mount Clemens
10. St. Louis
11. Sebawaing

Minnesota

1. Chasta
2. East Grand Forks
3. Moorhead

Montana

1. Billings
2. Chinook
3. Hardin
4. Missoula
5. Sidney

Nebraska

1. Bayard
2. Gering
3. Grand Island
4. Mitchell
5. Scottsbluff

Ohio

1. Findlay
2. Fremont
3. Ottawa

Oregon

1. Nyassa

South Dakota

1. Belle Fourche

Utah

1. Canterfield
2. Garland
3. Layton
4. Lewiston
5. West Jordan

Washington

1. Toppenish

Wyoming

1. Lovell
2. Torrington
3. Worland

Wisconsin

1. Green Bay

Total factories operating -73
Number of States 16

Factories not operated 1950-51

1. Fort Lupton, Colorado
2. Lyman, Nebraska
3. Wheatland, Wyoming
4. Sheridan, Wyoming
5. Blackfoot, Idaho
6. Paulding, Ohio
7. Holland, Mich.
8. Mt. Pleasant, Mich.

Factories Abandoned

1. Spanish Fork, Utah
2. Shelley, Idaho
3. Burley, Idaho

Table 34. - The Corn Wet-Milling Industry: Companies, location of plants, and corn sweeteners produced, 1950-51

Company	Location of Plant	CORN SWEETENERS SOLD (indicated by "x")				
		Corn Sirup		Unmixed		Refined corn sugar (dextrose)
		Low conversion	Regular	High conversion	Spray or pan dried	
American Maize-Products Co.	Roby, Ind.	x	x	x	x	x
Anheuser-Busch Inc.	St.Louis,Mo.	x	x	x		
Clinton Foods,Inc.	Clinton,Iowa	x	x	x	x	x
Corn Products Refining Co.	(Argo,Ill.	x	x	x		x
	(Pekin,Ill.	x	x	x		x
	(Kans.City,Mo.	x	x	x		x
	(Corpus Christi,Tex.					x 1/
The Hubinger Co.	(Keokuk,Iowa	x	x	x	x	
Penick & Ford,Ltd.	Cedar Rapids, Iowa	x	x	x		x
A.F.Staley Mgf.Co.	Decatur, Ill.	x	x	x		
Union Starch & Refining Co.	Granite City,Ill.		x	x		

1/ Dextrose produced from sorghum.

Table 35. Total Sugar Available for Domestic Consumption: Adjustment for Estimated Net Change in Invisibles, United States, 1935-50

Year	Total Sugar Available for Domestic Consumption (bags, as produced) 1/	Estimated Net Change in Invisibles (bags, refined) 2/	Adjusted Totals (bags as produced) 3/
1935	125,987,047	+ 261,680	125,725,367
1936	127,731,361	- 280,370	128,014,731
1937	126,563,285	+ 149,530	126,413,755
1938	125,837,673	- 355,140	126,192,813
1939	129,961,934	+ 3,757,010	126,204,924
1940	130,242,739	+ 4,971,960	125,270,779
1941	152,315,097	+11,327,100	140,987,997
1942	102,640,153	-20,149,530	122,789,683
1943	119,681,042	+ 1,028,040	118,653,002
1944	135,037,472	+ 261,680	134,775,792
1945	112,458,319	- 1,140,190	113,598,509
1946	105,090,947	- 130,840	105,221,787
1947	139,249,454	+ 6,635,510	132,613,944
1948	137,702,013	- 4,766,360	142,468,373
1949	142,353,490	- 2,093,460	144,482,387
1950 4/	155,445,573	+ 7,477,000	147,968,573

1/ Source: See Table 44.

2/ Source: Sugar Branch, PMA---Converted from raw value by application of conversion factor 1.07.

3/ For the purposes of this study, this column represents sugar usage by civilians and the military.

4/ Preliminary.

Table 36. Cane Sirup and Edible Molasses: United States production, imports, exports, and supply available for domestic consumption, 1935-50

Year	Production 1/			Imports 2/	Exports	Supply available for domestic consumption	
	Cane sirup	Edible Molasses	Total				
	1000 gals.	1000 gals.	1000 gals.	1000 gals.	1000 gals.	1000 gals.	1000 lbs.
1935 ...	23,727	5,512	29,239	1,819	98	30,960	359,136
1936 ...	24,509	5,526	30,035	1,809	121	31,723	367,987
1937 ...	21,670	5,228	26,898	2,156	110	28,944	335,750
1938 ...	23,844	3,880	27,724	2,169	61	29,832	346,051
1939 ...	20,524	3,882	24,406	2,288	103	26,591	308,456
1940 ...	22,264	4,891	27,155	3,778	17	30,916	358,626
1941 ...	13,360	2,706	16,066	5,357	15	21,408	248,333
1942 ...	18,638	5,400	24,038	7,202	79	31,161	361,468
1943 ...	18,416	7,732	26,148	1,224	80	27,292	316,587
1944 ...	21,027	10,690	31,717	2,852	53	34,516	400,386
1945 ...	19,897	6,922	26,819	1,871	175	28,515	330,774
1946 ...	28,711	15,181	43,892	622	290	44,224	512,998
1947 ...	24,450	13,589	38,039	650	1,100	37,589	436,032
1948 ...	20,270	5,146	25,416	1,031	51	26,396	304,628
1949 ...	13,390	4,016	17,406	1,197	5/	18,603	215,785
1950 ...	11,770	4,339	16,109	2,358 6/	5/	18,467	214,217

Sugar Branch, PMA

1/ Bureau of Agricultural Economics: Production of cane sirup and edible molasses is of the fall of the preceding year.

2/ Figures for 1935-38 were derived from Sugar Branch statistics; for 1939-47 from U. S. Tariff Commission and 1948-50 from Sugar Branch; original source was Department of Commerce.

3/ Sugar Branch, PMA: Computed from Department of Commerce statistics, 1935-48.

4/ Converted from gallons at 11.6 pounds per gallon.

5/ Department of Commerce, 1949-50, includes cane sirup and edible molasses exports under the classification "Sirup for table use and edible molasses."

6/ Includes January-November totals only.

Table 37. Refiner's Sirup: United States Production, Exports and Supply Available for Domestic Consumption, 1935-50

Year	Production of 1/ Refiner's Sirup	Sirups 2/ Exports	Supply Available	
	1000 gallons	1000 gallons	1000 gallons	1000 pounds 4/
1935	2,887	377	2,510	29,417
1936	(2,700)	284	2,416	28,316
1937	2,735	380	2,355	27,601
1938	(2,900)	307	2,493	29,218
1939	3,428	2,378	1,050	12,306
1940	(2,800)	1,179	1,621	18,998
1941	(2,600)	192	2,408	28,222
1942	(6,400)	342	6,058	71,000
1943	12,225	398	11,827	138,612
1944	14,996	300	14,696	172,239
1945	22,020	421	21,599	253,140
1946	18,211	3,896	14,315	167,772
1947	(10,000)	342	9,658	113,192
1948	4,107	307	3,800	44,536
1949	3,901	575 3/	3,326	38,981
1950	3,546	205 3/	3,341	39,157

1/ Bureau of Agricultural Economics: From 1929 to 1942, inclusive, figures for odd years, except 1941, are from Bureau of the Census; for even years and 1941 and 1947 quantities are estimated. Data from 1943-48 from the Sugar Branch, PMA.

2/ Assumed to be largely refiner's sirup. Includes a variety of sirups for table use and use by food industries. Does not include molasses, corn sirup (other than for table use), sirups and flavors for beverages, or honey, all of which are separately reported in official United States export statistics.

3/ Dept. of Commerce classification now includes quantities of exported edible molasses. 1950 figure includes January-November totals only.

4/ Converted from gallons at 11.72 pounds per gallon.

Table 38. Honey: United States Production, Imports, Exports and Supply Available for Domestic Consumption, 1935-50
(1,000 pounds)

Year	Domestic Production	Imports and In-shipments	Domestic Exports	Supply Available
1935	159,753	1,856	1,574	160,035
1936	177,495	2,362	1,128	178,729
1937	162,996	2,385	2,538	162,843
1938	223,003	2,432	3,442	221,993
1939	180,474	2,603	2,561	180,516
1940	205,767	2,698	3,363	205,102
1941	221,959	5,144	530	226,573
1942	177,672	21,202	335	198,539
1943	189,867	38,254	59	228,062
1944	188,917	24,811	177	213,551
1945	233,070	21,031	197	253,904
1946	213,814	19,935	198	233,551
1947	228,582	20,377	1,292	247,667
1948	206,305	9,283	11,108	204,480
1949	226,978	9,666	1,212	235,432
1950 1/	234,153	(9,500)	(1,300)	242,353

B.A.E., Department of Commerce

1/ Preliminary--imports and inshipments are exports estimated.

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Table 39. Production, Imports and Total Supply Available for Domestic Consumption, 1935-1950

MAPLE SUGAR

Year	Production 1/ (1000 pounds)	Imports (1000 pounds)	Total Supply Available (1000 pounds)
1935	1,241	1,920	3,161
1936	721	6,207	6,928
1937	779	6,050	6,829
1938	705	3,946	4,651
1939	366	9,622	9,988
1940	434	4,087	4,521
1941	387	4,628	5,015
1942	654	7,121	7,775
1943	578	4,556	5,134
1944	565	3,883	4,448
1945	237	3,959	4,196
1946	372	4,207	4,579
1947	305	4,064	4,369
1948	229	6,239	6,468
1949	292	7,094	7,386
1950	278	(5,163) 2/	5,441

MAPLE SIRUP

Year	Production 1/ (1000 pounds)	Imports (1000 pounds)	Total Supply Available (1000 gallons)	(1000 Pounds
1935	3,432	224	3,656	40,216
1936	2,401	28	2,429	26,719
1937	2,497	8	2,505	27,555
1938	2,770	4	2,774	30,514
1939	2,515	241	2,756	30,316
1940	2,597	24	3,021	33,231
1941	1,997	2	2,209	24,299
1942	2,915	436	3,351	36,861
1943	2,555	108	2,663	29,293
1944	2,568	163	2,731	30,041
1945	991	112	1,103	12,133
1946	1,328	202	1,530	16,830
1947	2,039	467	2,506	27,566
1948	1,445	445	1,890	20,790
1949	1,614	375	1,989	21,879
1950	1,946	(474) 2/	2,420	26,662

1/ B.A.E.--Does not include varying quantities produced on non-farm lands in Somerset County, Maine.

2/ Dept. of Commerce, total for January-October, 1950.

Table 40. Sorgo Sirup: Production, United States, 1935-1950

Year	Production (000) (gallons) 1/	Production (000) (pounds) 2/
1935	18,588	214,691.4
1936	16,230	187,456.5
1937	12,936	149,410.8
1938	12,481	144,155.6
1939	11,407	131,750.8
1940	10,199	117,798.4
1941	10,684	116,734.0
1942	10,568	122,060.4
1943	13,728	158,558.4
1944	11,868	137,075.4
1945	11,649	134,546.0
1946	9,850	113,767.5
1947	11,934	117,837.7
1948	9,845	113,709.8
1949	7,665	88,530.8
1950	6,012	69,438.6

1/ B.A.E. Production of fall of preceding year, assumed for consumption in calendar year following.

2/ Converted from gallons at about 11.55 pounds per gallon.

Table 41. Corn Grindings by the Wet Process; Domestic, Export and Total, United States, 1935-1950

Year	Wet Process Grindings, bushels		
	Domestic	Export 1/	Total
1935	56,172,154	2,147,029	58,319,183
1936	72,093,176	2,404,218	74,497,394
1937	65,517,842	2,884,360	68,402,202
1938	66,385,911	6,935,630	73,321,541
1939	69,097,391	8,146,725	77,244,114
1940	70,377,825	11,332,433	81,710,258
1941	99,367,019	10,933,247	110,300,266
1942	122,980,405	7,377,632	130,358,037
1943	122,398,301	6,056,535	128,454,854
1944	115,185,818	4,773,307	119,959,125
1945	115,479,093	3,462,798	118,941,891
1946	114,620,797	5,990,077	120,610,874
1947	133,241,609	6,031,570	139,273,179
1948	106,138,233	3,739,689	109,877,922
1949	111,339,804	4,834,289	116,174,093
1950	126,138,928	5,299,610	131,438,538

Compiled from trade sources by the Grain Branch, PMA

1/ Bushel--equivalent of products of corn shipped to points outside of the 48 States and the District of Columbia.

Derivation of Statistics on Total Sugar Supply Available for Domestic Consumption and Usage by Householders, Institutions and Industry, United States, 1935-50.

1. Previously published sugar distribution data, as collected by the Department of Agriculture for purposes related to the Sugar Act and its functions, are shown in Table 42. These data include sugar deliveries for domestic consumption and for export, by type of primary distribution, and the figures are expressed in terms of short tons, raw value. From the total of such deliveries are subtracted the deliveries for export in order to derive total deliveries for United States civilian and military consumption.

2. Total supply of sugar for domestic consumption: The data described above constitute the basic information from which total supply of sugar, liquid or crystalline, for domestic consumption, available during the years 1935-50, has been determined for purposes of this Project No.RM:c 137. As the information was to be used in comparing sugar distribution or usage with deliveries or usage of other types of sweeteners, it was considered necessary to establish sugar deliveries on a basis of deliveries as produced or as sold rather than as short tons, raw value. In addition, to the total distribution figures, as previously published, were added imports of liquid sugar entered under the liquid sugar quota for Cuba and Dominican Republic plus large quantities of "colored and flavored sirups," imported during 1942-44 and later classified as liquid sugar. Tables 43 and 44 present deliveries by primary distributors and liquid sugar imports in short tons and in 100 pound units, as produced. From the basic published series, deliveries for domestic consumption on an as produced basis were derived as follows:

a. Refiners' Refined Crystalline and Liquid Sugar - Liquid sugar deliveries for the years 1941-50 are available within the Department on the basis of refined sugar content of the product sold. Since no data on sugar content, as produced, are available, data on liquid sugar, both domestic and imported, are given in this study in terms of sugar content as reported. By subtracting liquid sugar figures from the total of Refiners' Refined, as previously published a residual figure representing Refiners' Refined Crystalline sugar was obtained for the years 1941-50. These residuals as well as the total Refiners' Refined figures for 1935-40 were converted from raw value figures to units, as produced, by the application of the conversion factors listed in Table 45.

b. Refiners' Raws - For 1935-50, figures for Refiners' Raws delivered for direct consumption, are published in terms of raw value (96°). These were used without conversion as data in terms of units, as produced, are unavailable.

c. Deliveries by Beet Processors - Figures in short tons, raw value were converted to 100 pounds, raw value and divided by the conversion factor 1.07 to give annual deliveries in terms of units, as produced.

d. Importers' Raws, Refined Sugar and Turbinadoes - Figures on raw sugar deliveries, 96° basis, and other deliveries, as produced, are available within the Department for the years 1940-50. For the years, 1935-39, a conversion factor of 1.068 (the average relationship of value, as produced, to raw value, 1940-50) was used in converting raw value to units, as produced.

e. Mainland Cane Deliveries - Deliveries of raw sugar and deliveries of other types of sugar for direct consumption by mainland cane mills are available separately for the years 1939-50, in terms of raw value. Raw sugar deliveries for these years has been listed as reported, while other deliveries are converted from raw value to units, as produced, by applying the conversion factor 1.065 to reported figures. This conversion factor for deliveries other than raw sugar is a weighted average of the "as produced" equivalents of refined sugar, magma, washed crystals, turbinadoes and plantation granulated (Refined sugar constituted approximately 75 percent of the total each year). For the years 1935-36, the total raw sugar and other deliveries were converted together from short tons, raw value by applying the factor 1.058. This factor is the weighted average conversion factor for combined raw and other sugar deliveries by mainland cane mills for the years 1939-49.

f. Liquid Sugar Imports - Such imports, on a basis of refined sugar content, are available within the Department for the years 1935-50. For the years, 1942-44, the sugar content of flavored and colored sirups imports, estimated from Tariff Commission analyses made during 1944, was added to liquid sugar imports.

3. Total Estimated Civilian Usage of Sugar, 1935-50 - Table 43 presented total beet and cane sugar distribution and liquid sugar imports, 1935-50. From the totals therein, direct deliveries of sugar to the military have been subtracted. However, sugar used in industrial products for military consumption is included with civilian industrial usage. The resultant figures have been adjusted for net changes in invisibles, 1935-50 (See Table 46). The final adjusted totals represent, for purposes of this study, an estimate of total civilian sugar usage for the years, 1935-50, and include all use categories as calculated in the following study of sugar usage by householders, institutions and industry.

4. Sugar Usage by Householders, Institutions and Industry, 1935-50 - The objective of this study was to construct time series reflecting sugar consumption by end-users. The data in Table 47 are estimates as no adequate data on consumption by end-users are available. While these estimates do not have a high degree of statistical accuracy, they probably give a fair picture of the relative magnitudes and trends in usage by industrial users, household consumers, and institutions.

a. Home use - An annual postwar rate of about 57 million bags, raw value, is indicated by the Census of Manufacturers: 1947 and USDA "Sugar Deliveries by Type of Buyer." Both these sources reported

the quantity of sugar delivered by primary distributors in consumer-size packages. 80/ Unfortunately there are no similar data on which to base estimates of household usage in earlier years. For the period 1935-46, the series is composed of residuals, after the subtraction of estimated industrial and institutional usage from total consumption.

b. Institutional Use - The only material on institutional consumption is an unpublished USDA estimate of 8,000,000 bags for the prewar years. This annual consumption figure was based on data on institutional population and school enrollment, and certain assumptions regarding attendance at restaurants and vacation resorts, together with estimated per capita sugar consumption. For the control period, and extrapolation was made on the basis of OPA regulations regarding institutional users. For the post-control period, the sharp increase was based on general information regarding greatly increased school enrollment and attendance at vacation resorts.

c. Industrial Usage - General - Several sources contributed to the estimates of industrial usage, either directly or as corroborative evidence. The most important was the Census of Manufactures. There follows a brief summary of the sources used and of the general nature of the adjustments which had to be made to adapt them to the purposes of this study.

(i) Census of Manufactures: 1937, 1939, and 1947. Probably the most complete and accurate data on industrial sugar consumption are reported by the Census, especially for 1939. It will be noted, however, that the figures used in this study are somewhat higher than the Census reports, as attempts were made to correct for under-enumeration. 81/ Before doing so, however, it was necessary to reclassify the Census data somewhat.

Two types of reclassification were needed, the first dealing with the sugar reported consumed by the individual industry; the second (and more important), with the classification of individual industries within the major classes.

In its reports by industry, Census classifies each establishment, and the materials it consumes, according to the industry in which it is primarily engaged. Reported sugar use by an industry, therefore, is not confined to the end-products of that industry, but also includes sugar used in the manufacture of secondary products belonging to other industries. In general, the resulting distortion

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80/ Census of Manufactures: 1947 Vol. II. - Sugar, Confectionery and Related Products. Table 6. The Census defined a consumer-size package as "25 pounds or less" for most of the standard types of sugar. The USDA defined it as "less than 100 pounds," for all types. Since container sizes between 25 and 100 pounds are relatively rare, these definitions were considered to include the same size groups.

81/ For a comparison of Census reported sugar use and estimates used in this study, by major industrial classes, see Table 48.

of reported sugar use largely cancels itself out when individual industries are combined into larger industrial groups as the secondary products of one industry generally fall within the same major industrial class as its primary product. The net degree of distortion, by major classes, was not considered sufficiently significant to justify correction except in the case of "Multiple and All Other Food Uses" and the "Canning and Preserving" classes.

The second type of reclassification consisted of transferring whole industries from one major class to another, to fit the industry groupings used in this study. 82/ This reclassification affected the Census data chiefly in the "Miscellaneous Food" category.

After being reclassified, the Census data were adjusted for the degree of under-reporting considered inherent in the method of enumeration itself, and to a lesser extent for consistency with data from other sources. It will be noted that the smallest adjustment was made in 1939 and the greatest in 1947. Since the objective of the study was to establish reasonable trends in usage by each industry group, and changes in the relative magnitude of usage by different groups, adjustments in official Census data were not always made even when small changes might have been indicated. Such small changes it is believed often result in a spurious accuracy of detail which cannot be justified in the light of the wide degree of error to which any individual figure is probably subject.

Reports on sugar consumption were obtained from more industries in 1939 than in any other Census. That year, all the major food industry groups and tobacco manufacturers reported sugar consumed. In 1947, however, data on sugar consumption were not collected from manufacturers of grain mill products, alcoholic beverages, miscellaneous foods (except flavorings), or tobacco. For each Census year estimates of sugar consumed in the industries not reporting had to be estimated on the basis of data derived from other sources.

It was also necessary to correct Census data for under-enumeration within the industries covered. In 1937 and 1939, the Census of Manufactures excluded establishments whose value of production was under $5000. Beginning with 1947, the monetary limitation was replaced by another excluding establishments which, during the year, had had no employees. The Census Bureau and other sources indicate that neither of these definitions of size-limit excluded significant quantities of sugar use from the reports. This is probably true except in the case of the bakery industry. In the 1947 Census a further cause of under-enumeration was introduced by the fact that the Standard Industrial Classification, revised in 1948, resulted in the elimination of a considerable number of establishments from the Census of Manufactures 1947, which would have been included in 1939 and previous Censuses.

82/ For a detailed breakdown of the major classes used in this study, and an analysis of the reclassification of Census data and OPA Registrations, see Table 49.

Establishments which sold through single retail outlets were, in 1945, transferred to the Retail Trade Division. This change probably had the greatest effect on the baking industry as it excluded the production of many hotels, restaurants and institutions, which were to a certain extent included in previous Censuses. Insofar as it also eliminated the output of many small family-type establishments, it resulted in some under-reporting in the soft drink and preserving, as well as the baking industries.

(ii) Sugar Deliveries by Type of Buyer: 1949 and 1950 - These reports made to the USDA cover 95 to 100 percent of total deliveries by all types of primary distributors except mainland cane mills. Reported deliveries to industrial users, however, probably represent a somewhat smaller percentage of the total than the 80 percent of total industrial sugar consumption reported by the Census in 1947. Primary distributors reported deliveries to industrial users only insofar as the latter purchased sugar directly from them. In addition, manufacturers must have ultimately obtained a large portion of the sugar which primary distributors reported delivering to secondary distributors (exclusive of consumer-size packages.) With respect to specified industrial classes, the degree of under-reporting is probably even greater than for industry as a whole since primary distributors reported deliveries under "Multiple and All Other Food Uses," when end-use was not entirely clear. For these reasons "Sugar Deliveries" proved inconclusive as a basis on which to estimate industrial sugar use, though it provided a rough guide to relative quantities of sugar consumed by different industrial classes. The preliminary estimates of industrial sugar use for 1950, however, are based almost entirely on reported "Sugar Deliveries" for that year as very little other data were available.

(iii) Registration of Industrial Users - OPA - This is the only report which gives sugar consumption by type of end-use. For this reason, and also because it is a more complete tabulation of sugar usage for the classes of users covered than any other source, the data obtained by the Registration should have been of great value for the present study. In practice, this was not so as the Registration included upward biases that could not be eliminated. 83/ The chief contribution of this study made by the Registration was the tabulation in four industries of users by volume of sugar use. This frequency distribution was of great value

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83/ Registration was required of all commercial establishments that wished authorization to use rationed foods during the war period. Sugar users originally were required to state the quantity of sugar they had used during 1941 in the manufacture of all products except those classified as "provisional." For most industry groups, the Registrations gave far higher sugar use during the base period than had been estimated for 1941 on the basis of the 1939 Census. Some of the difference reflected the usage of very small firms not covered by the Census. More important, however, was that the Registrations, when tabulated in 1945, included as part of base use, considerable sugar in addition to that consumed in 1941. Regulations had permitted upward adjustments in base use to be made in certain cases where a 1941 base would impose undue hardship. Also, a certain number of new users (chiefly veterans) who had not been in business in 1941, were given bases. There is, moreover, a presumption that some industrial users reported their 1941 sugar purchases (instead of use), thus including some inventory building.

in indicating the approximate degree of under-enumeration of small firms by the Census.

(iv) Production Series and Indexes - For all the major industrial classes, considerable use was made of series reporting production of end-products. Sugar use was estimated by applying factors of approximate sweetener content to reported volume of production of finished goods. The resulting series on total sweeteners was then adjusted to allow for corn sweetener utilization, and also to eliminate double-counting when one finished product (such as sweetener condensed milk) was used as the sweetening-ingredient in another finished product. This method is admittedly cumbersome and subject to a high degree of error. The degree of error was lessened to some extent, however, by reconciling sugar use estimated on this basis with that reported by Census for Census years. For inter-Census years, it was thought to provide a reasonable basis for interpolating sugar use.

Table 42. Calendar Year Distribution of Sugar by Primary Distributors, United States, 1935-50
(Short tons, raw value)

Year	Refiners' Raws	Refiners' Refined	Beet Processors	Importers	Mainland Cane, D.C.	TOTAL	Export 2/	For U. S. Consumption 3/
1935	10,183	4,564,943	1,478,660	614,628	86,028	6,754,442	120,514	6,633,928
1936	11,032	4,519,145	1,364,847	719,138	157,300	6,771,462	65,267	6,706,195
1937	13,946	4,714,835	1,245,498	615,432	155,890	6,745,601	74,199	6,671,402
1938	10,480	4,594,891	1,448,865	562,652	91,839	6,708,727	65,474	6,643,253
1939	6,176	4,468,679	1,810,456	572,807	141,461	6,999,579	132,061	6,867,518
1940	7,779	4,718,846	1,551,518	693,917	96,872	7,068,932	178,264	6,890,668
1941	8,573	5,518,103	1,952,597	564,044	96,478	8,139,795	70,338	8,069,457
1942	5,587	3,424,582	1,703,140	466,596	74,854	5,674,759	208,555	5,466,204
1943	15,196	4,621,179	1,525,735	515,640 1/	123,817	6,801,567	466,854	6,334,713
1944	9,875	5,606,726	1,156,309	522,931	164,968	7,460,809	313,459	7,147,350
1945	5,021	4,726,318	1,042,471	458,587	98,244	6,330,641	290,635	6,040,006
1946	3,939	4,012,110	1,379,447	480,152	148,289	6,023,937	403,229	5,620,708
1947	9,025	5,446,889	1,575,060	533,192	115,922	7,680,088	232,254	7,447,834
1948	2,343	5,151,817	1,656,663	511,693	97,755	7,420,271	77,300	7,342,971
1949	2,212	5,485,728	1,486,889	514,430	134,708	7,623,967	43,742	7,580,225
1950	2,635	5,925,327	1,747,690	553,838	104,398	8,333,888	60,398	8,273,490

1/ Includes flavored sirup from Mexico.

2/ For 1934-41, exports as reported by Department of Commerce; for subsequent years, deliveries for export as reported by primary distributors. War years include deliveries for liberated areas, lend lease and military relief.

3/ Includes deliveries for U. S. military forces at home and abroad.

Table 43.- Domestic Cane and Beet Sugar Distribution by Primary Distributors and Liquid Sugar Imports, United States, 1935-1950 1/

(Short tons, raw value)

Year	Refiners' Refined Crystalline	Refiners' Liquid	Refiners' Raws	Beet Processors	Importers'	Mainland Cane	Total Crystalline and Domestically-Produced liquid	Liquid Sugar Imports	Total
						(Short tons, Raw Value)			
1935	4,444,429		10,183	1,478,660	614,628	86,028	6,633,928	49,758	6,683,686
1936	4,453,878		11,032	1,364,847	719,138	157,300	6,706,195	69,560	6,775,755
1937	4,640,636		13,946	1,245,498	615,432	155,890	6,671,402	38,733	6,710,135
1938	4,529,417		10,480	1,448,865	562,652	91,839	6,643,253	38,783	6,682,036
1939	4,336,618		6,176	1,810,456	572,807	141,461	6,867,518	42,146	6,909,664
1940	4,540,582		7,779	1,551,518	693,917	96,872	6,890,668	38,633	6,929,301
1941	5,253,848	193,917	8,573	1,952,597	564,044	96,478	8,069,457	39,140	8,108,597
1942	3,132,335	153,442	5,587	1,648,377	451,609	74,854	5,466,204	3,481 3/	5,469,685 3/
1943	3,966,315	205,144	15,196	1,508,618	494,101	123,817	6,313,191	58,771 3/	6,371,962 3/
1944	5,026,122	267,830	9,875	1,155,624	522,931	164,968	7,147,350	65,494 3/	7,212,844 3/
1945	4,170,028	265,897	5,021	1,042,283	458,533	98,244	6,040,006	-	6,040,006
1946	3,366,854	245,431	3,939	1,376,045	480,150	148,289	5,620,708	-	5,620,708
1947	4,945,434	299,521	9,025	1,545,066	532,866	115,922	7,447,834	-	7,447,834
1948	4,710,052	369,281	2,343	1,655,846	511,693	97,755	7,342,971	18,106	7,365,192
1949	5,068,383	374,587	2,212	1,485,905	514,430	134,708	7,580,225	32,476	7,612,701
1950 2/	5,386,361	479,918	2,635	1,746,382	553,838	104,398	8,273,531	39,386	8,312,927

1/ Published sugar distribution figures (see Table 42) less exports plus imports of liquid sugar. Includes deliveries for use by U. S. Expeditionary Forces and excludes deliveries for liberated areas, lend-lease and military relief.
1935-40 All exports subtracted from refiners' refined crystalline.
1941-49 Export figures, available by type of primary distributor, subtracted from refined crystalline figures for each category.

2/ Preliminary

3/ Includes an estimated quantity of liquid sugar imported as flavored and colored sirups from Mexico and Cuba.

Table 44. - Domestic Cane and Beet Sugar Distribution by Primary Distributors and Liquid Sugar Imports, United States, 1935-1950 1/

(100-lb. units, as produced)

Year	Refiners'			Beet Processors	Importers'		Mainland Cane		Total Crystalline & Domestically-Produced liquid	Liquid Sugar Imports	Total
	Refined Crystalline	Liquid	Raws		Raws	Refined and Turbinados	Raws	Plantation, Granulated, etc.			
	(100-lb. units, as produced)										
1935	84,067,560		203,660	27,638,500	11,509,888		1,626,238		125,045,846	941,201	125,987,047
1936	84,246,280		220,640	25,511,160	13,467,004		2,973,534		126,418,618	1,315,743	127,734,361
1937	87,799,380		278,920	23,280,340	11,524,944		2,946,881		125,830,465	732,820	126,563,285
1938	85,541,400		209,600	27,081,580	10,536,554		1,736,087		125,105,221	732,452	125,837,673
1939	81,803,000		123,520	33,840,300	10,726,723		275,308	2,398,058	129,166,909	795,025	129,961,934
1940	85,532,160		155,580	29,000,340	257,778	12,729,496-	335,067	1,504,578	129,514,999	727,740	130,242,739
1941	98,846,655	3,648,378	171,460	36,497,140	439,744	10,131,907-	517,988	1,325,430	151,578,702	736,395	152,315,097
1942	58,887,942	2,884,718	111,740	30,810,785	399,671	8,068,995-	84,192	1,326,661	102,574,704	65,449 3/	102,640,153 3/
1943	74,603,313	3,858,610	303,920	28,198,467	547,029	8,724,287-	242,296	2,097,691	118,575,613	1,105,429 3/	119,681,042 3/
1944	94,098,258	5,014,267	197,500	21,600,449	198,660	9,588,750-	252,831	2,860,594	133,811,309	1,226,163 3/	135,037,472 3/
1945	77,496,850	4,941,495	100,420	19,481,925	130,556	8,448,706-	219,564	1,638,803	112,458,319	-	112,458,319
1946	62,931,850	4,587,501	78,780	25,720,467	118,249	8,864,262-	83,040	2,706,798	105,090,947	-	105,090,947
1947	92,438,019	5,598,526	180,500	28,879,740	147,885	9,821,899-	97,527	2,085,358	139,249,454	-	139,249,454
1948	88,038,355	6,902,451	46,860	30,950,393	325,818	9,259,872-	66,669	1,773,174	137,363,592	338,421	137,702,013
1949	94,736,131	7,001,624	44,240	27,773,925	400,609	9,241,144-	312,318	2,236,468	141,746,459	607,031	142,353,490
1950	2/100,679,645	8,970,423	52,700	32,642,642	418,603	9,957,484-	279,160	1,698,400	154,699,057	746,516	155,445,573

1/ Published sugar distribution figures less exports plus imports of liquid sugar. Includes deliveries for use by U.S. Expeditionary Forces and excludes deliveries for liberated areas, lend-lease and military relief.
1935-40 - All exports subtracted from refiners' refined crystalline.
1941-49 - Export figures, available by type of primary distributor, subtracted from refined crystalline figures for each category.

2/ Preliminary

3/ Includes an estimated quantity of liquid sugar imported as flavored and colored sirups from Mexico and Cuba.

Table 45. - Conversion factors for converting refined sugar to raw value 1/, 1935-50

1935-36	1,057,347	
1937	1,057,100	
1938	1,059,000	
1939	1,060,259	
1940	1,061,725	
1941	1,063,030	(1.07 for exports)
1942	1,063,829	
1943	1,063,308	
1944	1,068,271	
1945	1,076,180	
1946-1950	1,070,000	

Source: Sugar Branch, PMA.

1/ Representing the relationship between meltings of raw sugar and production of refined sugar.

Table 46.--Total Estimated Civilian Usage of Sugar, United States, 1935-50
(Thousands of 100-lb. units, as produced)

Year	Total sugar available for domestic and military use	Deliveries to armed forces	Total sugar available for civilian use	Net change in invisibles	Total estimated civilian consumption
	1/	2/		3/	
1935	125,990	-	125,990	∕ 260	125,730
1936	127,730	-	127,730	- 280	128,010
1937	126,560	-	126,560	∕ 150	126,410
1938	125,840	-	125,840	- 350	126,190
1939	129,960	-	129,960	∕ 3,760	126,200
1940	130,240	-	130,240	∕ 4,970	125,270
1941	152,320	1,790	150,530	∕ 11,330	139,200
1942	102,640	4,180	98,460	- 20,150	118,610
1943	119,680	5,860	113,820	∕ 1,030	112,790
1944	135,040	8,620	126,420	∕ 260	126,160
1945	112,460	8,330	104,130	- 1,140	105,270
1946	105,090	650	104,440	- 130	104,570
1947	139,250	1,090	138,160	∕ 6,640	131,520
1948	137,700	1,400	136,300	- 4,770	141,160
1949	142,350	1,080	141,310	- 2,090	143,440
1950 4/	155,450	1,210	154,240	∕ 7,480	146,760

1/ Source: Table 44.

2/ Source: U.S.D.A.

3/ Source: Estimates of Sugar Branch, P.M.A.

4/ Preliminary

Table 47. - Sugar Distribution and Estimated Usage, United States, 1935, 1937, 1939-50
(Thousands of 100 pound units, as produced)

Industrial Usage	1935	1937	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950 2/
Bakery and Allied Products; cereals and cereal products	11,500	12,700	13,180	13,830	14,670	12,900	13,830	14,210	14,390	14,110	16,920	18,800	19,460	19,460
Confectionery and related products	10,370	10,750	10,900	11,870	13,360	11,680	11,960	13,740	12,520	11,310	12,990	13,940	14,030	14,690
Ice cream and dairy products	2,520	3,180	3,360	3,740	4,390	3,830	4,300	5,050	5,980	6,820	6,350	5,990	5,710	5,710
Beverages	4,580	6,450	9,250	10,000	12,800	11,780	12,800	13,460	11,780	12,240	15,330	17,210	17,020	17,020
Canned, bottled, frozen foods; jams, jellies, preserves, etc.	4,490	5,980	6,260	7,010	7,850	7,380	8,790	11,310	9,250	11,400	11,590	12,720	12,250	13,280
Multiple and all other food uses	1,310	2,060	2,190	2,610	3,000	3,150	3,230	3,080	2,430	2,710	3,650	3,930	4,300	4,490
Non-food products	560	560	560	750	1,130	600	1,090	650	450	280	430	470	750	750
TOTAL INDUSTRIAL USE	35,330	41,680	45,700	49,810	57,200	51,320	56,000	61,500	56,800	58,870	67,260	73,060	73,520	75,400
HOTELS, RESTAURANTS, INSTITUTIONS	8,040	8,040	8,040	8,410	9,630	7,480	7,200	9,350	9,350	8,220	10,280	11,220	12,630	12,610
HOME USE	82,360	76,690	72,460	67,050	72,370	59,810	49,590	55,310	39,120	37,480	53,980	56,880	57,290	58,750
TOTAL ESTIMATED CIVILIAN USAGE 1/	125,730	126,410	126,200	125,270	139,200	118,610	112,790	126,160	105,270	104,570	131,520	141,160	143,440	146,760

1/ See Table 46.

2/ Preliminary.

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Table 48.—Industrial Consumption of Sugar by Major Classes, Reported and Adjusted
(thousands of 100-pound units, as produced)

Class 1/	1950		1949		1947		1939		1937	
	Deliveries by type of buyer	Adjusted	Deliveries by type of buyer	Adjusted	Census of mfrs.	Adjusted	Census of mfrs.	Adjusted	Census of mfrs.	Adjusted
Bakery and allied products	12,724	19,460	12,116	19,460	11,391 2/	16,920	11,751 2/	13,180	10,282 2/	12,700
Confectionery and related products	14,377	14,690	12,791	14,030	12,629	12,990	10,271	10,900	10,417	10,750
Ice cream and dairy products	5,074	5,710	4,446	5,710	6,361	6,350	3,272	3,360	1,354 3/	3,180
Beverages	15,116	17,020	14,265	17,020	14,927	15,330	9,163	9,250	6,356	6,450
Canned, bottled, frozen foods	11,010	13,280	8,857	12,250	10,089	11,590	5,990	6,260	6,026	5,980
Multiple and all other food uses	4,993	4,490	4,015	4,300	-	3,650	2,809 4/	2,190	1,898 4/	2,060
Non-food products	780	750	737	750	-	430	398 5/	560	387 5/	560
Total	64,074	75,400	57,227	73,520	55,397	67,260	43,654	45,700	36,720	41,680

1/ For individual industries included in each class, see Appendix Table 49.

2/ Excludes sugar used in dessert preparations. In 1947 and 1937, also excludes sugar used in grain mill products.

3/ Excludes sugar used in ice cream, which was not reported.

4/ For 1939 includes meat products and miscellaneous food preparations (except flavoring extracts and flavoring sirups). For 1937 includes flour and other grain mill products and miscellaneous food preparations (except flavoring extracts and flavoring sirups.)

5/ Tobacco only.

Table 49.--Classification of Industrial Users of Sugar

(Census of Manufactures: 1947, and OPA Registration of Industrial Users Regrouped to Conform with Classification used in Sugar Deliveries by Type of Buyer)

Class No.	Sugar Deliveries by Type of Buyer (reported by primary distributors to U. S. Dept. of Agriculture)	Census of Manufactures: 1947	Office of Price Administration Registration of Industrial Users[1/]
1	Bakery and allied products: Bread, rolls, sweet goods, dessert preparations, doughnuts, biscuits, crackers, cookies, pretzels, crullers, baking mixes and batters, bakers' supply houses, breakfast and other prepared cereals and cereal paste products.	BAKERY PRODUCTS: Bread and other bakery products; (except biscuits, crackers, and pretzels); biscuits, crackers, and pretzels. GRAIN MILL PRODUCTS: Flour and meal; prepared animal feeds; cereal preparations; rice cleaning and polishing; blended and prepared flour. MISCELLANEOUS FOOD PREPARATIONS: Food preparations not elsewhere classified: "Desserts (ready to mix)" and "Bakers Supplies"	R-1200 classes 1, 2, 3: Bread and other bakery products, baking mixes, including batters, breakfast cereals; and cereal paste products such as spaghetti and macaroni.
2	Confectionery and related products: Candy, candied fruits, and other confectionery products, chocolate and cocoa products, chewing gum, confectioners' supply houses.	CONFECTIONERY AND RELATED PRODUCTS: Confectionery products, chocolate and cocoa products; chewing gum. MISCELLANEOUS FOOD PREPARATIONS: Food preparations not elsewhere classified: "Confectioners supplies."	R-1200 class 9: Candy; chocolate; cocoa; chewing gum.

Table 49.--Classification of Industrial Users of Sugar - contd.

Class No.	Sugar Deliveries by Type of Buyer (reported by primary distributors to U. S. Dept. of Agriculture)	Census of Manufactures: 1947	Office of Price Administration Registration of Industrial Users[1]
3	Ice cream and dairy products: Ice cream, ice cream mix, ices, sherbets, frozen custard, sweetened condensed milk (bulk and case goods), creamery butter, cheese and cheese spreads, chocolate milk, miscellaneous dairy products.	DAIRY PRODUCTS: Creamery butter; natural cheese, concentrated milk; ice cream; special dairy products; plastic cream and bulk products.	R-1200 class 4: Ice cream; ices; sherbets, frozen custards; and mixes used for these purposes. R-1200 class 5 (in part): Condensed milk in containers of one gallon or less; cheese; other dairy products not included in other items. (Frozen eggs and sugared egg yolks excluded.) Bulk sweetened condensed milk not reported on R-1200.
4	Beverages: Alcoholic and non-alcoholic beverages, drink mixes, fountain sirups, flavoring and coloring extracts.	BEVERAGES: Bottled soft drinks, malt liquors; malt; wines and brandy; distilled liquors except brandy. MISCELLANEOUS FOOD PREPARATIONS: Flavorings; flavoring extracts, sirups and fruit juices n.e.c. for soda fountain use or for the manufacture of soft drinks, and colors for bakers' and confectioners' use.	R-1200 class 6 (in part): Bottled beverages (alcoholic and non-alcoholic); flavoring and coloring extracts; fountain sirups; drink mixes; brandied fruits; maraschino cherries; fountain fruits. (Pickled fruits and vegetables, and relishes excluded.)

Table 49.--Classification of Industrial Users of Sugar - contd.

Class No.	Sugar Deliveries by Type of Buyer (reported by primary distributors to U. S. Dept. of Agriculture)	Census of Manufactures: 1947	Office of Price Administration Registration of Industrial Users 1/
5	Canned, bottled and frozen foods, jams, jellies, preserves, etc.; Canned, frozen, bottled and dried fruits, vegetables, fruit juices, vegetable juices, soups, soup mixes, baked beans, pickled fruits and vegetables, relishes, vegetable sauces, and seasoning, jams, jellies, preserves, marmalades, fruit butters, mayonnaise, and condiments.	CANNED AND PRESERVED FOODS: Canned sea food; cured fish; canning and preserving, except fish; dehydrated fruits and vegetables; pickles and sauces; frozen foods.	Canned, bottled, frozen and preserved foods not reported on R-1200 except for items listed below. R-1200 class 11: Dehydrated and dried soup and soup mixes. R-1200 class 6 (in part): Pickled fruits and vegetables; relishes. R-1200 class 7: Mayonnaise and salad dressing.
6	Multiple and all other food uses: Deliveries to buyers making products falling into two or more of the above categories and for which estimates of amounts going into each category are not feasible. Also deliveries for miscellaneous food uses, such as meat curing, sirup blending, etc.	MISCELLANEOUS FOOD PREPARATIONS: Leavening compounds, shortening and cooking oils, oleomargarine, corn products. Vinegar and cider, manufactured ice, macaroni and spaghetti, liquid, frozen, and dried eggs, food preparations not elsewhere classified (excluding "desserts, ready to mix," "bakers' and confectioners' supplies," "flavoring extracts and other flavoring agents n.e.c.") 2/ MEAT PRODUCTS: Meat packing, wholesale; prepared meats; poultry dressing, wholesale.	R-1200 class 12: Canned and bottled foods (not reported in other items); table sirups. R-1200 class 5 (in part): Frozen eggs and sugared egg yolks. R-1200 class 8: Products fried in fat (except bakery products) such as nuts, potato chips. R-1200 class 10: Sandwiches. R-1200 class 16: All other classes; food. Meat packing not reported on R-1200

Table 49. - Classification of Industrial Users of Sugar - contd.

Class No.	Sugar Deliveries by Type of Buyer (reported by primary distributors to U. S. Dept. of Agriculture)	Census of Manufactures: 1947	Office of Price Administration 1/ Registration of Industrial Users
7	Non-food uses: All non-food uses, such as tobacco, pharmaceutical, etc.	TOBACCO MANUFACTURERS GROUP: Cigarettes; cigars; chewing and smoking tobacco; tobacco stemming and redrying.	R-1200 class 13: Experimental, educational. R-1200 class 14: Pharmaceuticals (internal). R-1200 class 15: Pharmaceuticals (external). R-1200 class 17: All other classes: non-food.

1/ OPA Form R-1200, issued pursuant to Ration Orders 3, 13, and 16. (Form approved Budget Bureau No. 08-R 719)

2/ For detailed list of industries and products covered by the Census under "Food preparations n.e.c." See p. 198.

Table 49.--Classification of Industrial Users of Sugar - contd.

CENSUS MANUFACTURES: 1947

Food Preparations, Not Elsewhere Classified

(Part of Standard Industrial Classification No. 2099, excluding processed eggs, mincemeat, and sandwich spread.)

Baked beans (not canned)
Bakers', confectioners', and household supplies, including

Chili pepper and powder
Coconut, desiccated or shredded
Marshmallow creme
Pie and cake fillings
Sugar, powdered

Bouillon cubes
Brown bread (canned Boston and other)

Chocolate and cocoa, instant

Desserts (ready to mix)

"Health foods"

Ice-cream cones and wafers
Italian, Spanish, Mexican, and Chinese cakes and other "native" preparations

Meat pies
Molasses (mixed or blended)

Peanut products (except peanut candy and salted peanuts)
Pectin
Potato chips

Ravioli

Spices and meat seasoning
Sweetening sirups, including honey, maple sirup, and sorghum

Establishments primarily engaged in roasting coffee (except coffee roasting done by wholesale grocers)

Table 50.--Estimated Sugar Usage by Industrial Users and by Householders and Institutions, in Thousands of 100-pound Units and as a Percent of Total Sugar Available for Domestic Civilian Consumption, United States, 1935, 1937, 1939-50

Year	SUGAR USAGE BY:				Total sugar available for domestic civilian consumption
	Householders and institutions		Industrial users		
	(Thousands of 100-lb. units)	(Percent of total)	(Thousands of 100-lb. units)	(Percent of Total)	(Thousands of 100-lb. units)
1935	90,400	71.9	35,330	28.1	125,730
1937	84,730	67.0	41,680	33.0	126,410
1939	80,500	63.8	45,700	36.2	126,200
1940	75,460	60.2	49,810	39.8	125,270
1941	82,000	58.9	57,200	41.1	139,200
1942	67,290	56.7	51,320	43.3	118,610
1943	56,790	50.4	56,000	49.6	112,790
1944	64,660	51.3	61,500	48.7	126,160
1945	48,470	46.0	56,800	54.0	105,270
1946	45,700	43.7	58,870	56.3	104,570
1947	64,260	48.9	67,260	51.1	131,520
1948	68,100	48.2	73,060	51.8	141,160
1949	69,920	48.7	73,520	51.3	143,440
1950 1/	71,360	48.7	75,400	51.3	146,760

Source: See table 47.

1/ Preliminary.

Table 51 - Index of Industrial Usage of Sugar, by Category of Industry, United States, 1935, 1937, 1939-50
(1935-39 = 100)

Product or Business of Buyer	1935	1937	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950 1/
Bakery and Allied Products; cereals and cereal products	92.3	101.9	105.8	111.0	117.7	103.5	111.0	114.0	115.5	113.2	135.8	150.9	156.2	156.2
Confectionery and related products	97.2	100.7	102.1	111.2	125.2	109.4	112.1	128.7	117.3	106.0	121.7	130.6	131.4	137.6
Ice cream and dairy products	83.4	105.3	111.3	123.8	145.4	126.8	142.4	167.2	198.0	225.8	210.3	198.3	189.1	189.1
Beverages	67.8	95.4	136.8	147.9	189.3	174.3	189.3	199.1	174.3	181.1	226.8	254.6	251.8	251.8
Canned, bottled, frozen foods; jams, jellies, preserves, etc.	80.5	107.2	112.3	125.7	140.8	132.3	157.6	202.8	165.9	204.4	207.8	228.1	219.7	238.1
Multiple and all other food uses	70.7	111.1	118.2	140.8	161.9	170.0	174.3	166.2	131.1	146.2	196.9	212.1	232.0	242.3
Non-food products	100.0	100.0	100.0	133.9	201.8	107.1	194.6	116.1	80.4	50.0	76.8	83.9	133.9	133.9
TOTAL INDUSTRIAL USAGE	86.4	101.9	111.7	121.8	139.8	125.5	136.9	150.3	138.9	143.9	164.4	178.6	179.7	184.3

Source: Table 47.

1/ Preliminary.

Table 52.- Industrial Usage of Dextrose, by Category of Industry
United States, 1935 - 1942
(100 lb. units, as produced)

Product or Business of Buyer	1935	1936	1937	1938	1939	1940	1941	1942
Bakery and allied products; cereal and cereal products	1,162,430	1,472,327	1,550,830	1,625,462	1,816,144	2,118,635	2,720,159	3,045,124
Confectionery and related products	161,011	221,648	230,623	237,928	269,644	268,871	311,391	654,125
Ice cream and dairy products	93,623	121,205	160,489	172,251	183,704	185,170	270,316	277,168
Beverages	140,120	169,071	263,228	337,349	392,424	445,194	672,186	913,393
Canned, bottled, frozen foods; jams, jellies, preserves, etc.	45,764	60,655	74,742	151,977	365,730	385,619	855,752	860,269
Multiple and all other products	27,471	44,139	79,287	68,555	87,899	117,540	150,851	179,663
Non-food products	53,075	68,675	84,401	73,834	90,306	93,575	174,299	159,775
TOTAL DOMESTIC	1,683,494	2,157,720	2,443,600	2,667,356	3,205,911	3,614,604	5,154,954	6,089,517

Source: Reports of dextrose manufacturers to Sugar Branch, PMA.

Table 53 - Industrial Usage of Dextrose, by Category of Industry, United States, 1943 - 1950
(100 lb. units, as produced)

Product or Business of Buyer	1943	1944	1945	1946	1947	1948	1949	1950
Bakery and allied products; cereals and cereal products	3,139,357	3,052,280	2,887,643	2,684,073	3,569,392	3,503,862	3,650,096	4,204,953
Confectionery and related products	521,077	480,103	438,439	452,243	447,262	290,427	290,928	322,869
Ice cream and dairy products	263,404	238,702	221,459	257,593	241,971	289,094	284,008	279,388
Beverages	845,562	719,871	986,948	1,206,525	1,050,295	677,025	771,000	835,186
Canned, bottled, frozen foods; jams, jellies, preserves, etc.	692,715	578,201	662,630	498,883	547,501	721,909	822,869	793,312
Multiple and all other products	212,196	195,473	214,885	185,145	237,103	296,246	321,069	416,721
Non-food products	266,315	274,184	270,758	283,207	335,373	342,901	322,681	434,895
TOTAL DOMESTIC	5,940,626	5,538,814	5,682,762	5,567,669	6,428,897	6,121,464	6,462,651	7,287,324

Source: Reports of dextrose manufacturers to Sugar Branch, PMA.

Table 54 - Index of Industrial Usage of Dextrose, by Category of Industry, United States, 1935 - 1942
(1935-39 = 100)

Product or Business of Buyer	1935	1936	1937	1938	1939	1940	1941	1942
Bakery and allied products; cereals and cereal products	76.2	96.5	101.7	106.5	119.1	138.9	178.3	199.6
Confectionery and related products	71.8	98.9	102.9	106.1	120.3	120.0	138.9	292.0
Ice cream and dairy products	64.0	82.9	109.7	117.8	125.6	126.6	184.8	189.5
Beverages	53.8	64.9	101.1	129.5	150.7	170.9	258.1	350.7
Canned, bottled, frozen foods, jams, jellies, preserves, etc.	32.7	43.4	53.5	108.7	261.7	275.9	612.2	615.5
Multiple and all other products	44.7	71.8	129.0	111.5	143.0	191.2	245.4	292.3
Non-food products	71.7	92.7	113.9	99.7	122.0	126.3	235.3	215.7
TOTAL DOMESTIC	69.2	88.7	100.5	109.7	131.9	148.6	212.0	250.4

Source: Table 52.

Table 55 - Index of Industrial Usage of Dextrose, by Category of Industry, United States, 1943 - 1950

(1935-39 = 100)

Product or Business of Buyer	1943	1944	1945	1946	1947	1948	1949	1950
Bakery and allied products; cereals and cereal products	205.8	200.1	189.3	176.0	234.0	230.0	239.3	275.6
Confectionery and related products	232.4	214.2	195.6	201.7	199.5	129.6	129.8	144.0
Ice cream and dairy products	180.1	163.2	151.4	176.1	165.4	197.7	194.2	191.0
Beverages	324.7	276.4	379.0	463.3	403.3	260.0	296.0	320.7
Canned, bottled, frozen foods, jams, jellies, preserves, etc.	495.6	413.7	474.1	356.9	391.7	516.5	588.7	567.6
Multiple and all other products	345.2	318.0	349.6	301.2	385.7	481.9	522.3	677.9
Non-food products	359.5	370.2	365.5	382.3	452.8	462.9	435.6	587.1
TOTAL DOMESTIC	244.3	227.8	233.7	229.0	264.4	251.7	265.8	299.7

Source: Table 53.

Table 56.—Industrial Usage of Corn Sirup Unmixed, by Category of Industry, United States, 1935-1942
(100-lb. units, as produced)

Product or Business of Buyer	1935	1936	1937	1938	1939	1940	1941	1942
Bakery and allied products, cereals and cereal products	471,340	573,989	549,818	560,046	579,846	579,856	677,612	2,156,108
Confectionery and related products	4,724,277	5,646,519	5,587,314	5,605,985	5,670,616	5,946,972	6,496,351	7,744,768
Ice cream and dairy products	8,131	9,270	9,997	10,842	14,456	23,767	38,833	915,321
Breweries and brewery supply houses	402,926	452,668	419,637	332,941	286,680	243,279	280,790	287,028
Soft drinks	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	234 1/	322,469
Canned, bottled, frozen foods, jams, jellies, preserves, etc.	178,818	212,599	175,070	154,558	151,610	178,599	216,966	517,238
Blended sirups	2,641,180	3,663,082	2,650,072	3,063,357	3,376,480	3,057,172	3,531,742	6,806,852
Miscellaneous food products 2/	284,331	305,720	303,344	295,601	339,266	338,014	378,013	577,140
Non-food products 2/	413,816	458,400	392,091	380,352	455,232	459,124	538,902	791,897
TOTAL DOMESTIC	9,124,820	11,222,246	10,087,343	10,403,664	10,874,186	10,826,783	12,159,443	20,118,821
TOTAL DOMESTIC, DRY BASIS 3/	7,327,230	9,011,464	8,100,136	8,354,142	8,731,971	8,693,907	9,764,033	16,155,413

1/ Total of last three months of 1941.

2/ 1935-42 estimated.

3/ Based on 43° sirups with average solids content of 80.3 percent. Computed Sugar Branch, PMA.

n.a. - not available

Source: Reports of Corn Refiners to Price Waterhouse; distributed through Grain Branch, PMA.

Table 57 Industrial Usage of Corn Sirup Unmixed, by Category of Industry, United States, 1943-1950
(100 lb. units, as produced)

Product or Business of Buyer	1943	1944	1945	1946	1947	1948	1949	1950
Bakery and allied products, cereals and cereal products	1,739,380	1,615,346	1,666,610	1,555,248	1,592,150	1,010,171	1,006,983	1,057,642
Confectionery and related products	7,785,632	7,894,563	7,716,186	7,556,294	8,189,321	7,145,506	7,221,207	7,596,513
Ice cream and dairy products	515,499	595,903	743,162	593,225	562,143	305,224	311,631	323,441
Breweries and brewery supply houses	318,713	376,815	374,161	271,876	359,752	327,770	429,475	374,989
Soft drinks	56,551	61,853	83,256	162,180	77,195	1,887	5,423	18,261
Canned, bottled, frozen foods, jams, jellies, preserves, etc.	526,633	666,528	842,587	944,500	1,105,148	625,329	697,359	990,942
Blended sirups	5,900,130	5,925,972	5,940,993	5,554,804	6,458,026	2,721,866	3,139,903	3,229,063
Miscellaneous food products 1/	445,385	419,500	420,917	510,532	577,355	377,929	468,464	730,336
Non-food products 1/	612,671	508,009	479,508	458,025	471,043	429,517	432,112	519,758
TOTAL DOMESTIC	17,900,594	18,064,489	18,267,380	17,606,684	19,392,133	12,945,199	13,712,557	14,840,945
TOTAL DOMESTIC, DRY BASIS 2/	14,374,177	14,505,785	14,668,706	14,138,167	15,571,883	10,394,995	11,011,183	11,917,279

Source: Reports of Corn Refiners to Price - Waterhouse; distributed through Grain Branch, PMA.

1/ 1943-44 estimated.
2/ Based on 43° sirups with average solids content of 80.3 percent. Computed Sugar Branch, PMA.

Table 58. - Index of Industrial Usage of Corn Sirup Unmixed, by Category of Industry
United States, 1935-1942

(1935-39 = 100)

Product or Business of Buyer	1935	1936	1937	1938	1939	1940	1941	1942
Bakery and allied products; cereals and cereal products	86.18	104.93	100.51	102.38	106.00	106.01	123.88	394.16
Confectionery and related products	86.74	103.66	102.58	102.92	104.11	109.18	119.27	142.19
Ice cream and dairy products	77.15	87.96	94.86	102.87	137.16	225.51	368.46	8684.91
Breweries and brewery supply houses	106.32	119.45	110.73	87.85	75.65	64.20	74.09	75.74
Soft drinks	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Canned, bottled, frozen foods, jams, jellies, preserves, etc.	102.46	121.81	100.31	88.56	86.87	102.33	124.31	296.36
Blended sirups	86.35	116.48	86.64	100.15	110.38	99.95	115.46	222.53
Miscellaneous food products	93.02	100.02	99.24	96.71	110.10	110.59	123.67	188.82
Non-food products	98.53	109.15	93.36	90.56	108.39	109.32	128.32	188.55
TOTAL DOMESTIC	88.23	108.51	97.53	100.59	105.14	104.68	117.57	194.53

Source: Table 56

n.a. - not available.

Table 59. - Index of Industrial Usage of Corn Sirup Unmixed, by Category of Industry
United States, 1943-1950

(1935-39 = 100)

Product or Business of Buyer	1943	1944	1945	1946	1947	1948	1949	1950
Bakery and allied products; cereals and cereal products	371.98	295.31	304.68	284.32	291.07	184.67	184.09	193.35
Confectionery and related products	142.94	144.94	141.66	138.73	150.35	131.18	132.57	139.46
Ice cream and dairy products	4891.25	5654.16	7051.41	5628.75	5333.83	2896.08	2956.88	3068.93
Breweries and brewery supply houses	84.10	99.43	98.73	71.74	94.93	86.49	113.33	98.95
Soft drinks	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Canned, bottled, frozen foods, jams, jellies, preserves, etc.	301.74	381.90	482.77	541.17	633.21	358.29	399.56	567.77
Blended sirups	192.89	193.73	194.22	181.60	211.13	88.98	102.65	105.56
Miscellaneous food products	145.72	137.25	137.71	167.03	188.89	123.65	153.27	238.94
Non-food products	145.88	120.96	114.71	109.06	112.16	102.27	102.89	123.76
TOTAL DOMESTIC	173.08	174.66	176.63	170.24	187.50	125.16	132.58	143.50

Source: Table 57

n.a. - not available.

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Table 60. - Industrial Usage of Primary Sweeteners and Individual Sweetener Usage as a Percent of Total Industry Usage, United States, 1935-50

Year	Industry Usage of Sugar: Thousands of 100 lb. units 1/	Sugar: Percent of total	Dextrose: Thousands of 100 lb. units 2/	Dextrose: Percent of total	Corn Sirup: Thousands of 100 lb. units 3/	Corn Sirup: Percent of total	Total Industry Usage: Thousands of 100 lb. units
1935	35,330	76.6	1,683	3.6	9,125	19.8	46,138
1936	n. a.	—	2,158	-	11,222	--	n. a.
1937	41,680	76.9	2,444	4.5	10,087	18.6	54,211
1938	n. a.	—	2,667	-	10,404	—	n. a.
1939	45,700	76.4	3,206	5.4	10,874	18.2	59,780
1940	49,810	77.5	3,615	5.6	10,827	16.9	64,252
1941	57,200	78.9	5,155	7.1	12,159	16.8	72,514
1942	51,320	66.2	6,089	7.9	20,119	25.9	77,528
1943	56,000	70.2	5,941	7.4	17,900	22.4	79,841
1944	61,500	72.3	5,539	6.5	18,064	21.2	85,103
1945	56,800	70.4	5,683	7.0	18,267	22.6	80,750
1946	56,870	71.0	5,568	7.0	17,607	22.0	80,045
1947	67,260	72.3	6,429	6.9	19,392	20.8	93,081
1948	73,060	79.3	6,121	6.6	12,945	14.1	92,126
1949	73,520	78.5	6,463	6.9	13,713	14.6	93,696
1950 4/	75,400	77.3	7,287	7.5	14,841	15.2	97,528

Source: 1/ Table 47; 2/ Tables 52 and 53; 3/ Tables 56 and 57; 4/ Preliminary.

June 25, 1942

TO THE MEMBERS OF THE TECHNICAL ADVISORY COMMITTEE OF
THE CORN INDUSTRIES RESEARCH FOUNDATION

Gentlemen: Corn Syrup Analysis Report No. 3

The Analysis of Acid-Enzyme Converted Syrups

Your Sub-Committee on the analysis of corn syrups has collected and evaluated all of the data on the composition of acid-enzyme converted syrups and has agreed upon what it believes to be a reliable determination of the constitutents. The Sub-Committee submits the following analytical figures on acid-enzyme-converted corn syrups for your approval.

TABLE I.

Composition of Acid-Enzyme Converted Corn Syrup
(Dry Substance Basis)

Dextrose Equivalent(1)	Per Cent Constituent			
	Dextrose(2)	Maltose(3)	Higher Sugars(4)	Dextrines(5)
61	35.8	33.2	17.2	13.8
62	36.6	33.8	16.7	12.9
63	37.5	34.2	16.1	12.2
64	38.4	34.8	15.2	11.6
65	39.5	35.0	14.5	11.0
66	40.6	35.2	13.8	10.4

(1) Lane-Eynon Method

(2) Sichert-Bleyer Method

(3) In the Sub-Committee's preliminary report, dated April 6, 1942, the values for maltose content by Hurd's propionylation method - Hurd and Liggett, J. Am. Chem. Soc. 63, 2659 (1941 - and Cantor's methylation method - Cantor and Smith, Am. Chem. Soc. paper, Sept. 1940 - were reported. These values, which were obtained with two different samples of syrup, check very well and were used as the basis for the maltose content in the proposed analysis.

(4) Higher sugars (Maltotriose and Maltotetrose) and non-reducing dextrines account for all the carbohydrate substance other than dextrose and maltose. The content of higher sugars found by

Hurd and Bonner of 17.3% for a syrup containing 36.1% dextrose and 33.4% maltose agrees very well with the estimated dextrine content, and the higher sugar values are based upon this determination.

(5) Since there was a marked discrepancy between the values for dextrines as determined by Hurd and Bonner and by Cantor and Smith, the research laboratories of the Corn Products Refining Company and the A. E. Staley Manufacturing Company each analyzed two samples of acid-enzyme converted syrups. The dextrine content was determined by a modification of the tentative A.C.A.C. method:

> Eight grams of syrup is dissolved in exactly 8 cc of distilled water in a 50 cc round bottom flask and 89 cc of absolute alcohol is added. The flock is shaken for several hours or until the dextrine precipitates leaving a clear, supernatant liquid. The insoluble gummy, white mass is treated twice again in the same manner. Upon completion the final alcohol insoluble residue is dissolved in water, transferred to a weighed dish, dried and weighed. The amount of reducible substance in this residue is then determined by the Lane-Eynon method. The weight of reducing substance is calculated as a disaccharide having 50% of the reducing value of dextrose, and this weight is deducted to give the dextrine value.

The two sets of analyses varied considerably as to the weight of precipitated carbohydrate, but the corrected values were in agreement that syrup in the 63 - 64 D.E. range contains approximately 12% dextrine.

The percentages of constituents in Table I have been plotted against dextrose equivalent in Figure I. Since the D/D.E. ratio changes somewhat with the brand of enzyme used for the conversion, the dextrose value is more significant than the dextrose equivalent. Therefore, the Sub-Committee recommends, that in case of doubt, the analysis of a particular syrup be taken from the curves of the ordinate which passes through the determined dextrose point.

As in the case of acid-converted syrups, it is recommended that the curves be read to an accuracy of ± 0.2% so that the sum of the constituents adds up to 100%.

The commercial basis analyses can be readily calculated from the dry-substance values.

The sub-committee realizes that the proposed analysis is not absolute, but it is accurate within the limits of experimental error of the best analytical procedures that have been developed to date. The

noteworthy differences between an acid-enzyme-converted syrup and a straight acid-converted syrup of the same D.E. is that the former is lower in dextrose and dextrine and higher in maltose and higher sugars. The total reducing sugar content of acid-enzyme-converted syrups is in the range of 87 to 89%.

Respectfully submitted

S. M. Cantor
CORN PRODUCTS REFINING COMPANY

W. W. Moyer
A. E. STALEY MANUFACTURING COMPANY

October 3, 1941

TO THE MEMBERS OF THE TECHNICAL ADVISORY COMMITTEE OF THE CORN INDUSTRIES RESEARCH FOUNDATION

Gentlemen:

In order to reach an agreement on a temporarily acceptable set of analytical data for acid converted starch products falling in the corn sirup range, the Sub-Committee considering this subject met at Decatur on Saturday, September 20, 1941.

The Sub-Committee considered all of the available information on corn sirup analysis and arrived at the following set of figures (Table I) based upon the five methods cited below:

(1) The Sichert-Bleyer method for the determination of dextrose in the presence of other reducing sugars. (Modification of either Staley or Corn Products).

(2) The analytical method for sugar mixtures involving the fractional distillation of their methyl ethers. (Hurd & Cantor, J. Am. Chem. Soc. 60, 2677 (1938); Cantor and Smith, presented before the Division of Sugar Chemistry, A.C.S., Detroit, Sept. 1940).

(3) A method similar to (2) except involving the use of the propionate esters of the sugars. (Hurd, Gordon and Liggett, to appear in October, 1941 issue of the Journal of the American Chemical Society).

(4) An amplification of the statistical method of Freudenberg and Kuhn. (This method involves the assumption that all the bonds in starch will rupture at an equal rate. From this assumption can be calculated the distribution of molecular sizes at any point during the hydrolysis.)

(5) The tentative A.O.A.C. method for the determination of dextrines. (Modified by extending the number of precipitations from one to three).

TABLE I

Dextrose Equivalent	Percent Constituents(a)			
	Dextrose	Maltose	Higher Sugars(b)	Dextrines
25	8.5 (1)	9.4 (4)	29.1 (4)	53.0 (4)
30	12.0 (1)	--	--	--
35	16.0 (1)	--	--	--
40	20.3 (1)	--	--	--
42	22.0 (1)(2)	20.8 (2)(3)(4)	20.2 (2)(4)	37.0 (5)
45	24.7 (1)	--	--	--
50	29.5 (1)	25.0 (4)	--	--
55	35.0 (1)	--	--	--
60	40.3 (1)	28.8 (4)	7.9 (4)	23.0 (4)

(a) Numbers in parenthesis after the figures in the table refer to one or more of the foregoing methods by which the point was established.

(b) The higher sugars refer to the trisaccharide, maltotriose, and the tetrasaccharide, maltotetrose, which for the most part are not included in the A.O.A.C. dextrine precipitation method, but which exert a notable reducing power. Since there is no familiar general terminology which includes these two sugars, the descriptive phrase "higher sugars" has been chosen.

The data in the foregoing table have been plotted in the attached set of curves. It will be noted that the range of dextrose equivalents takes in the majority of corn sirup types manufactured by the industry. From these curves three typical sirups would have the following analyses (Table II):

TABLE II

CSU ANALYSIS

Carbohydrate Dry Substance Analyses

Constituent Percent	28	42	55
Dextrose	10.5	22.0	34.8
Maltose	11.5	20.8	27.3
Higher Sugars	28.2	20.2	11.6
Dextrines	49.8	37.0	26.3
Commercial Analyses (43° Bé Basis)			
Moisture	20.5*	19.7	18.9
Dextrose	8.3	17.6	28.1
Maltose	9.1	16.6	22.0
Higher Sugars	22.3	16.2	9.4
Dextrines	39.5	29.6	21.3
Ash	0.3	0.3	0.3

*Estimated. Unavailable in C.I.R.F. Tables

It is recommended that the curves be read to an accurach of ± 0.2% but that the sum of the constituents add up to 100%.

It is believed that the figures cited here offer a closer approach to the actual analysis of acid converted sirups than those heretofore available. The maltose values are considerably lower than those presently accepted. However, it is quite probable that in previous maltose determinations a portion of the sugars referred to as "higher sugars" was included as maltose.

The Sub-Committee realizes that in view of this report it will be necessary to revise the data with respect to enzyme converted sirups and also those sirups made by the superimposition of enzyme conversion upon acid conversion.

In this respect it realizes that the maltose values for this type of sirup will have to be revised upward. Some data on these sirups are available, and a report is being prepared for submission in the near future.

Respectfully submitted,

W. W. Moyer
A. E. STALEY MANUFACTURING COMPANY

S. M. Cantor
CORN PRODUCTS REFINING COMPANY

October 3, 1941

Table 61.-The Freezing Points of Sweetener Solutions Expressing Concentration as the Percentage of Actual Dry Solids

	Percentage dry solids	Freezing point °C.
Corn Sirup	4.20	- 0.32°
	8.28	- 0.65°
	12.44	- 1.02°
	16.60	- 1.42°
	20.81	- 1.99°
	24.91	- 2.45°
	29.05	- 3.07°
	33.20	- 3.73°
Corn Sirup Solids	2.482	- 0.105°
	4.974	- 0.218°
	9.205	- 0.480°
	15.778	- 0.883°
	23.680	- 1.500°
	45.380	- 4.020°
Sucrose	2.5	0.13
	4.2	.23
	8.0	.50
	14.0	.90
	20.0	1.50
	25.0	2.00
	37.5	4.00
Dextrose	4.0	.50
	8.0	1.00
	12.0	1.50
	18.0	2.40
	30.0	4.80

Table 62.--Refined Cane Sugar: Average wholesale price per cwt., New York, gross, by months, 1935-50

(Dollars)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1935	4.30	4.30	4.38	4.97	5.25	5.25	5.15	5.10	5.16	5.30	5.27	4.97	4.95
1936	4.76	4.65	4.74	5.00	5.00	5.00	4.83	4.72	4.70	4.58	4.72	4.80	4.79
1937	4.99	5.00	4.80	4.80	4.77	4.64	4.70	4.70	5.09	4.89	4.77	4.75	4.82
1938	4.75	4.75	4.66	4.58	4.65	4.51	4.43	4.30	4.56	4.64	4.55	4.49	4.57
1939	4.34	4.30	4.39	4.43	4.50	4.50	4.42	4.40	5.73	5.37	4.90	4.70	4.66
1940	4.53	4.50	4.50	4.50	4.50	4.46	4.35	4.35	4.35	4.35	4.35	4.36	4.42
1941	4.40	4.45	4.87	5.10	5.05	5.00	5.05	5.31	5.29	5.25	5.25	5.25	5.02
1942	5.40	5.45	5.46	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.56
1943	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60
1944	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.60	5.50	5.50	5.50	5.50	5.57
1945	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
1946	5.50	5.83	6.00	6.00	6.00	6.02	6.10	6.10	6.78	7.60	7.76	8.00	6.47
1947	8.09	8.20	8.20	8.25	8.25	8.25	8.25	8.38	8.40	8.40	8.40	8.40	8.29
1948	8.21	7.82	7.75	7.75	7.60	7.51	7.75	7.75	7.75	7.75	7.75	7.75	7.76
1949	7.99	8.00	7.96	8.10	8.02	7.87	7.85	7.85	7.90	8.05	8.05	8.05	7.97
1950	8.05	7.92	7.74	7.70	7.70	7.70	7.97	8.22	8.25	8.25	8.25	8.25	8.00

Source: Net price reported by Lamborn and Co., converted to gross price, subject 2 percent discount, net cash, 10 days, Sugar Branch, PMA.

Table 63.--Dextrose Hydrate: Average wholesale price per cwt., in bags, New York, gross, by months, 1935-50 1/

(Dollars)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1935	3.49	3.54	3.59	3.78	4.05	4.04	4.04	4.05	4.07	4.18	4.16	3.83	3.90
1936	3.66	3.46	3.55	3.75	3.74	3.75	3.75	3.75	3.75	3.73	3.76	3.80	3.70
1937	3.94	3.91	3.99	4.05	4.05	4.03	4.03	4.03	4.13	4.01	3.84	3.84	3.99
1938	3.82	3.73	3.67	3.54	3.60	3.52	3.50	3.32	3.58	3.63	3.55	3.52	3.58
1939	3.38	3.30	3.44	3.50	3.50	3.50	3.50	3.50	4.28	4.38	3.91	3.70	3.66
1940	3.55	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.53	3.51
1941	3.58	3.62	3.87	4.05	4.05	4.11	4.15	4.32	4.35	4.35	4.35	4.35	4.10
1942	4.45	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
1943	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
1944	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
1945	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
1946	4.50	4.50	4.50	4.50	4.50	4.50	6.90	7.77	7.66	7.30 1/	6.95	7.08	5.89
1947	6.82	6.82	7.04	7.20	7.20	7.38	7.45	7.45	7.42	7.26	7.12	7.05	7.18
1948	6.91	6.40	6.40	6.40	6.25	6.15	6.15	6.31	6.40	6.40	6.40	6.40	6.38
1949	6.40	6.40	6.40	6.50	6.50	6.50	6.50	6.50	6.50	6.70	6.70	6.70	6.53
1950	6.70	6.82	6.40	6.35	6.35	6.35	6.46	6.87	6.90	6.90	6.90	6.90	6.66

1/ Paper bag base from October 1946 to date.

Source: Corn Products Refining Co. reports to Sugar Branch, PMA.

Table 64.--Corn Sirup, Unmixed, 43° Be': Average wholesale price per cwt., in barrels, carload lots, New York, gross by months, 1935-50 1/

(Dollars)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1935	3.64	3.64	3.60	3.65	3.68	3.68	3.68	3.68	3.68	3.68	3.47	3.23	3.61
1936	3.13	3.14	3.20	3.23	3.30	3.30	3.53	4.04	4.05	3.92	3.90	3.90	3.55
1937	3.86	3.86	3.88	4.35	4.41	4.41	4.30	3.86	3.86	3.74	3.30	3.12	3.90
1938	3.18	3.11	3.09	3.17	3.19	3.17	3.18	3.05	3.04	2.98	3.03	3.13	3.11
1939	3.17	3.09	3.07	3.09	3.12	3.12	3.05	3.03	3.26	3.04	2.94	3.00	3.08
1940	3.01	3.06	3.13	3.26	3.27	3.31	3.34	3.41	3.45	3.44	3.41	3.46	3.30
1941	3.46	3.41	3.46	3.51	3.51	3.52	3.61	3.61	3.61	3.61	3.61	3.61	3.54
1942	3.64	3.71	3.75	3.84	3.84	3.77	3.74	3.74	3.74	3.74	3.74	3.74	3.75
1943	3.74	3.74	3.74	3.74	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73	3.73
1944	3.73	3.73	3.73	3.73	3.75	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.05
1945	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27	4.27
1946	4.27	4.27	4.27	4.27	4.27	4.27	6.11	6.55	6.44	6.00	4.99	4.83	5.04
1947	4.85	4.93	5.51	5.85	5.86	6.54	6.79	7.21	7.44	7.25	7.28	7.28	6.40
1948	7.33	7.06	6.94	6.94	6.99	7.00	7.00	6.89	6.59	6.29	5.97	5.96	6.75
1949	6.08	5.91	5.85	5.85	5.96	6.00	6.04	6.04	6.02	5.98	5.92	6.02	5.97
1950	6.02	6.02	6.02	6.03	6.17	6.32	6.48	6.57	6.60	6.62	6.73	6.84	6.37

1/ Subject to 2 percent discount, net cash, 10 days.

Source: Corn Products Refining Co. reports to BAE, computed Sugar Branch, PMA.

Table 65.--New corn cost per bushel to wet millers, by months, 1935-49 1/
(cents per bushel)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1935	50.20	47.73	46.74	56.11	55.08	53.19	57.10	51.38	54.79	50.99	29.36	25.50	48.12
1936	29.79	32.93	35.07	38.83	38.80	38.82	51.13	70.66	70.40	70.04	68.01	67.31	50.97
1937	68.88	68.86	76.43	92.68	94.40	86.10	84.01	72.81	78.42	39.17	25.83	27.77	60.22
1938	29.30	25.48	28.55	31.60	32.22	31.45	32.04	27.70	28.13	21.35	23.31	27.92	28.25
1939	29.37	26.66	26.17	26.45	28.09	33.66	27.41	24.38	26.21	21.36	23.88	29.07	26.53
1940	30.48	30.03	32.35	36.87	43.39	44.41	44.33	44.74	42.21	40.54	38.25	32.16	38.26
1941	34.89	36.94	40.52	41.33	41.91	41.29	37.98	38.00	35.12	29.82	33.24	37.04	37.32
1942	40.75	39.89	38.73	43.11	46.49	44.76	45.51	43.26	42.14	34.48	37.03	45.73	41.91
1943	52.83	53.33	57.13	59.43	62.33	62.43	62.83	62.83	62.83	61.09	55.83	62.73	59.62
1944	63.61	64.01	64.91	64.91	64.91	64.91	64.91	64.91	64.91	63.76	58.86	63.66	64.05
1945	64.36	64.66	64.51	65.01	66.11	67.51	67.51	67.61	67.61	67.91	66.41	67.61	66.39
1946	66.06	67.56	70.36	70.56	86.24	91.52	147.25	120.81	127.76	110.28	55.16	47.97	88.47
1947	50.15	59.49	77.29	86.86	103.10	132.66	135.88	151.25	156.33	143.90	139.33	148.68	115.71
1948	155.84	129.26	137.27	134.61	120.70	120.86	119.51	113.62	103.45	72.60	61.52	71.31	111.34
1949	74.32	65.83	77.07	80.66	78.64	81.44	83.21	67.88	72.35	60.88	64.64	74.99	73.50

1/ Market price of No. 3 Yellow Corn, Chicago less proceeds for Corn Oil and Gluten feed per bushel of corn.

Source: Computed Sugar Branch, PMA.

Table 66.--Corn, No. 3 yellow, weighted average market price per bushel, Chicago, by months, 1935-49
(cents per bushel)
Calendar Year Basis

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1935	90.8	87.7	83.3	89.0	87.6	85.1	84.8	80.6	83.2	82.0	62.1	59.0	81.3
1936	60.8	61.3	60.8	63.2	63.2	64.0	85.8	113.5	112.1	106.6	104.7	107.2	83.6
1937	112.2	111.2	116.0	135.0	134.9	122.4	118.4	104.5	105.9	66.1	53.4	56.1	103.0
1938	59.3	56.9	57.9	58.6	57.7	57.0	58.7	53.6	52.7	44.7	46.0	51.0	54.5
1939	51.5	48.1	47.5	48.7	51.2	51.2	48.0	45.0	54.0	48.3	49.7	56.3	50.0
1940	58.5	57.6	57.9	62.5	68.6	65.8	65.3	66.0	64.5	64.3	64.5	61.5	63.1
1941	63.6	62.3	65.6	69.1	71.7	73.7	73.7	74.5	75.1	69.5	70.7	75.9	70.4
1942	81.8	81.9	81.7	82.3	85.3	84.5	86.0	84.4	84.1	77.3	80.5	89.4	83.3
1943	96.5	97.0	100.8	103.1	106.0	106.1	106.5	106.5	106.5	106.5	106.5	113.4	104.6
1944	114.2	114.6	115.5	115.5	115.5	115.5	115.5	115.5	115.5	114.2	109.3	114.1	114.6
1945	114.8	115.1	114.9	115.4	116.5	117.9	117.9	118.0	118.0	118.3	116.8	118.0	116.8
1946	116.5	118.0	120.8	121.0	144.8	152.8	216.7	193.1	189.4	181.9	139.2	134.0	152.3
1947	133.2	141.9	173.1	178.2	177.9	209.7	216.9	234.6	251.3	240.3	242.3	261.1	205.0
1948	271.1	225.3	230.1	231.8	230.6	231.6	213.6	195.1	180.8	147.0	138.1	142.4	203.1
1949	142.8	127.1	133.7	137.0	135.8	135.3	140.2	130.7	131.2	115.2	115.7	129.6	131.2

Source: BAE Feed Statistics and The Feed Situation.

Table 67.--Corn sirup solids: Prices per hundredweight, carloads, Chicago and New York, 1947-50

	Chicago (dollars)	New York (dollars)
1947		
January	6.23	6.86
February	6.34	6.99
March	6.68	7.33
April	6.68	7.33
May	6.68	7.33
June	6.92	7.34
July	7.20	7.67
August	7.76	8.38
September	8.26	8.45
October	8.38	7.96
November	8.40	7.96
December	8.21	7.96
1947 average	7.31	7.63
1948		
January	8.01	7.82
February	7.59	7.39
March	7.45	7.31
April	7.36	7.31
May	7.33	7.22
June	7.22	7.08
July	7.22	7.08
August	7.45	7.25
September	7.69	7.40
October	7.69	7.40
November	6.40	6.98
December	6.21	6.93
1948 average	7.30	7.26

Table 67.--Corn sirup solids: Prices per hundredweight, carloads, Chicago and New York, 1947-50 (contd.)

	Chicago (dollars)	New York (dollars)
1949		
January	6.30	7.05
February	6.12	6.87
March	6.05	6.81
April	6.05	6.81
May	6.16	6.92
June	6.20	6.96
July	6.20	6.96
August	6.20	6.96
September	6.20	6.98
October	6.16	6.94
November	6.10	6.88
December	6.20	6.98
1949 average	6.16	6.93
1950		
January	6.20	6.98
February	6.20	6.98
March	6.20	6.98
April	6.20	6.98
May	6.38	7.16
June	6.56	7.34
July	6.75	7.51
August	6.86	7.64
September	6.90	7.68
October	6.92	7.70
November	7.03	7.81
December	7.10	7.88
1950 average	6.61	7.39

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